US007009640B1

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Ishii et al.

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(54) **COLOR REPRODUCTION SYSTEM FOR CARRYING OUT COLOR CORRECTION BY CHANGING OVER COLOR CORRECTION PARAMETERS ACCORDING TO IMAGES OF PHOTOGRAPHED SUBJECTS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 935 days.

(21) Appl. No.: **09/583,521**

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(30) **Foreign Application Priority Data**

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Jun. 18, 1999 (JP) 11-172772

(51) **Int. Cl.**
H04N 9/73 (2006.01)

(52) **U.S. Cl.** **348/223.1**; 358/518

(58) **Field of Classification Search** 348/223.1, 348/222.1, 234, 235, 29, 223; 358/518, 520, 358/523, 1.9; 382/162, 164, 165, 167
See application file for complete search history.

(56) **References Cited**

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6,037,950 A * 3/2000 Meir et al. 345/427
6,643,029 B1 * 11/2003 Kumada et al. 358/1.9

* cited by examiner

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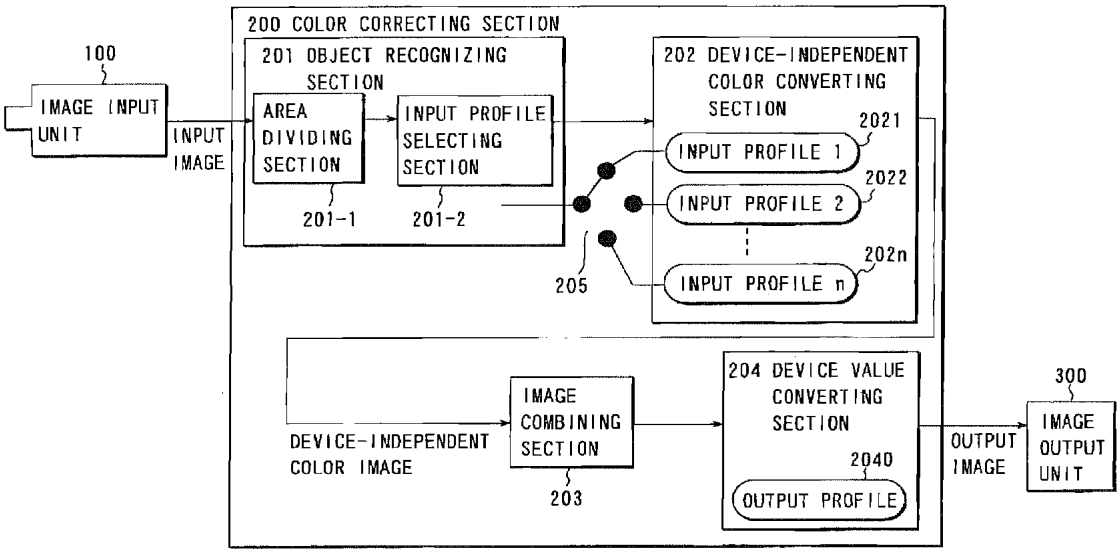
(57) **ABSTRACT**

A color reproduction system has a color image input section, and a color correcting section for correcting colors of a subject image obtained by photographing a subject by the color image input section. The color correcting section corrects colors by changing over a plurality of color correction parameters according to a subject image signal from the color image input section.

2 Claims, 30 Drawing Sheets



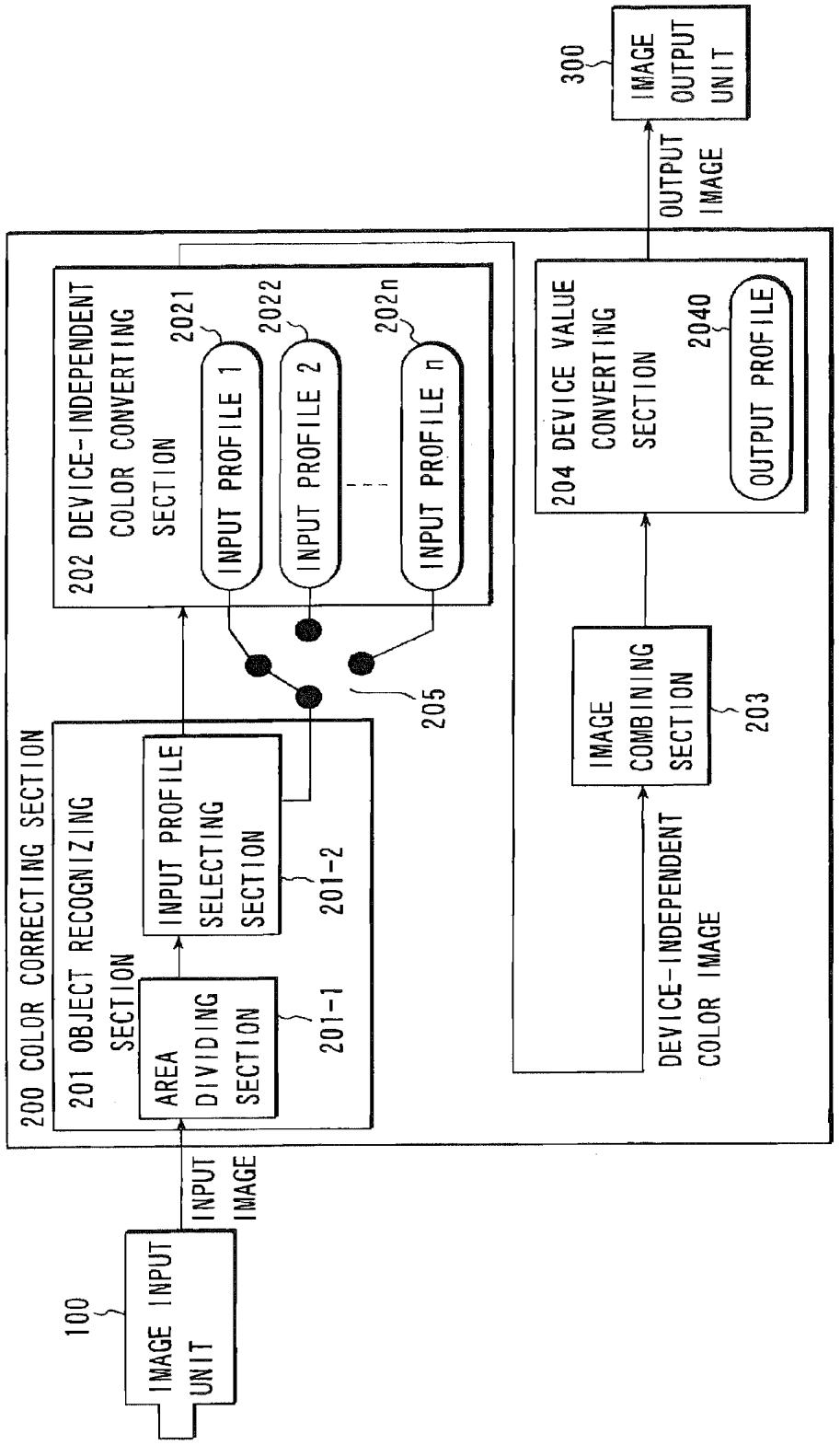

100
IMAGE INPUT UNIT
INPUT IMAGE
200 COLOR CORRECTING SECTION
201 OBJECT RECOGNIZING SECTION
AREA DIVIDING SECTION
201-1
INPUT PROFILE SELECTING SECTION
201-2
202 DEVICE-INDEPENDENT COLOR CONVERTING SECTION
2021
INPUT PROFILE 1
2022
INPUT PROFILE 2
202n
INPUT PROFILE n
205
DEVICE-INDEPENDENT COLOR IMAGE
IMAGE COMBINING SECTION
203
204 DEVICE VALUE CONVERTING SECTION
2040
OUTPUT PROFILE
OUTPUT IMAGE
300
IMAGE OUTPUT UNIT

FIG. 1

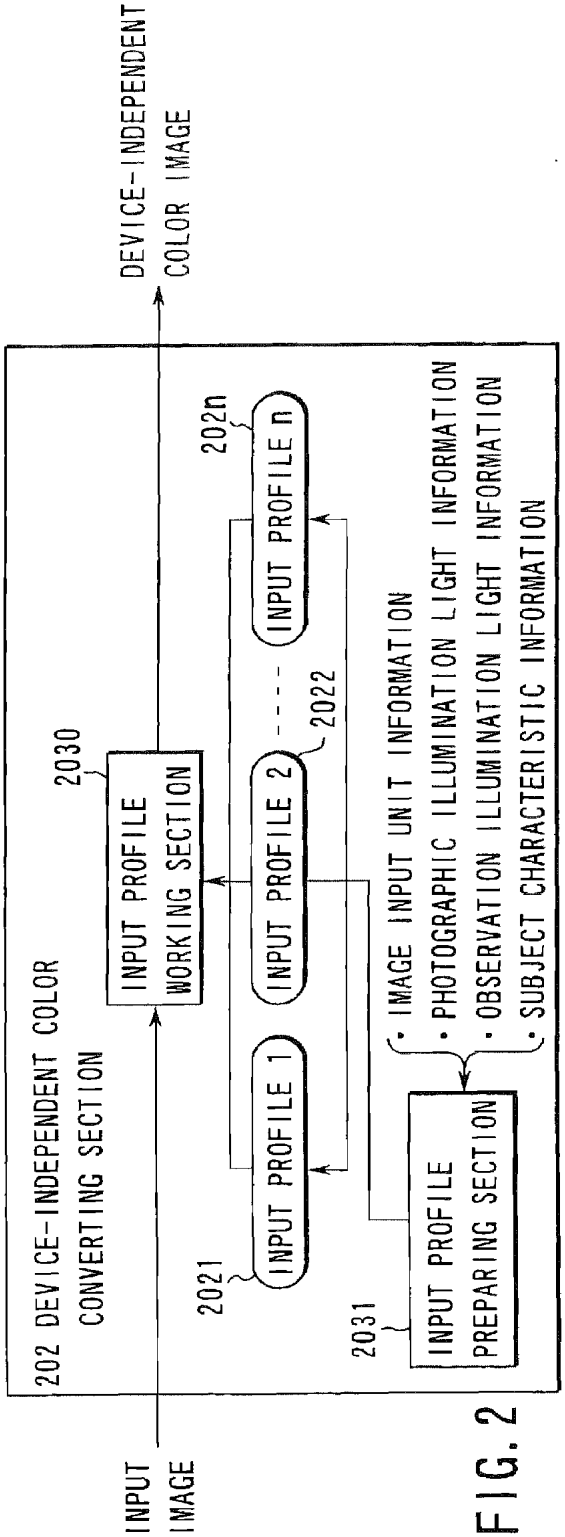

INPUT IMAGE
202 DEVICE-INDEPENDENT COLOR CONVERTING SECTION
INPUT PROFILE WORKING SECTION
2030
INPUT PROFILE 1
INPUT PROFILE 2
INPUT PROFILE n
2021
2022
202n
INPUT PROFILE PREPARING SECTION
2031
• IMAGE INPUT UNIT INFORMATION
• PHOTOGRAPHIC ILLUMINATION LIGHT INFORMATION
• OBSERVATION ILLUMINATION LIGHT INFORMATION
• SUBJECT CHARACTERISTIC INFORMATION
DEVICE-INDEPENDENT COLOR IMAGE

FIG. 2

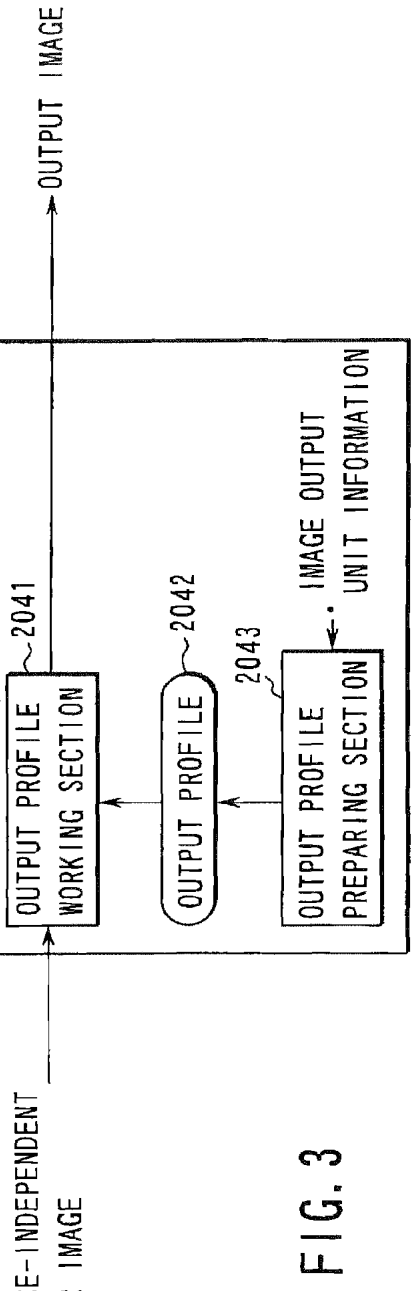

DEVICE-INDEPENDENT COLOR IMAGE
204 DEVICE VALUE CONVERTING SECTION
OUTPUT PROFILE WORKING SECTION
2041
OUTPUT PROFILE
2042
OUTPUT PROFILE PREPARING SECTION
2043
• IMAGE OUTPUT UNIT INFORMATION
OUTPUT IMAGE

FIG. 3

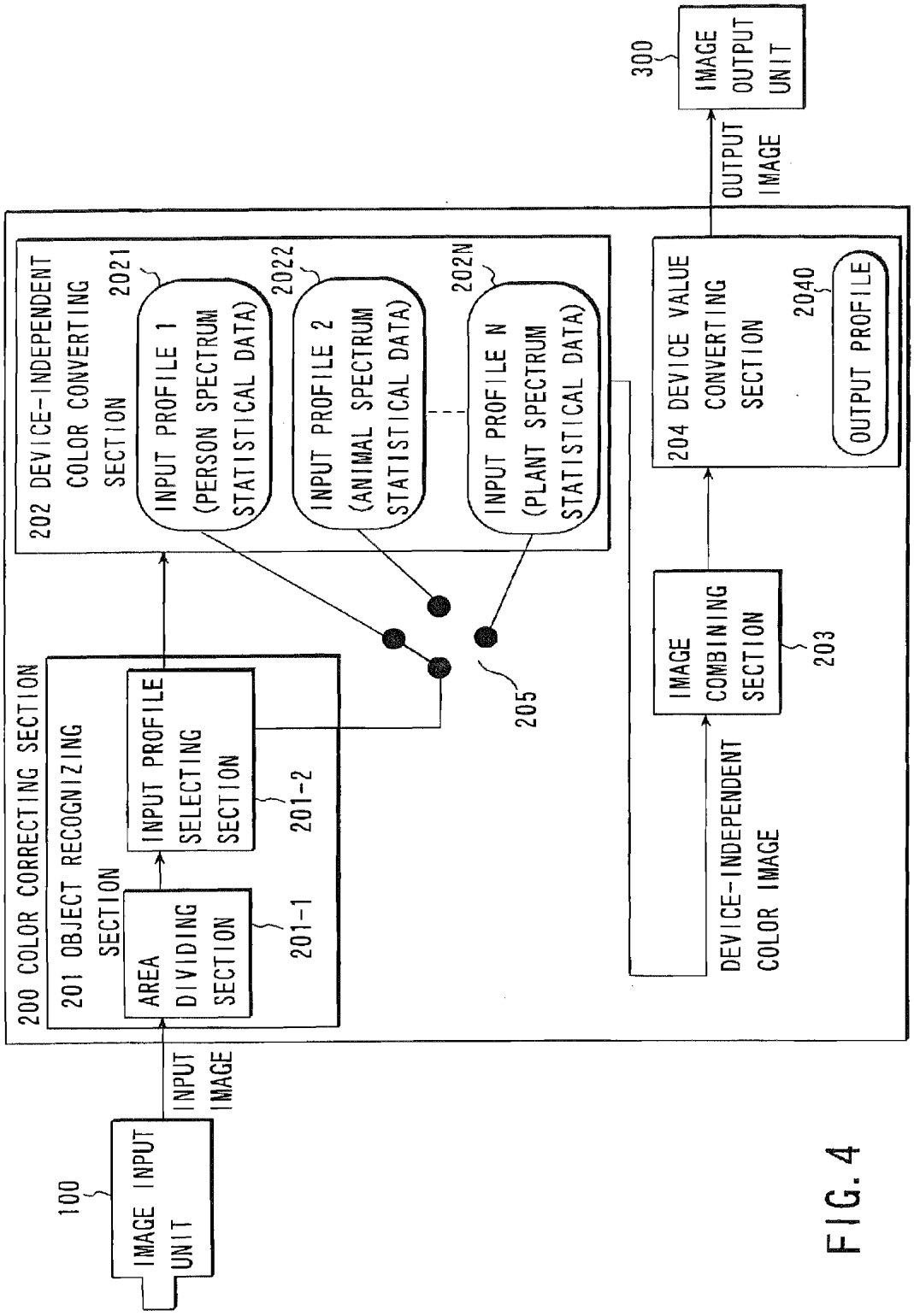

100
IMAGE INPUT UNIT
INPUT IMAGE
200 COLOR CORRECTING SECTION
201 OBJECT RECOGNIZING SECTION
AREA DIVIDING SECTION
201-1
INPUT PROFILE SELECTING SECTION
201-2
202 DEVICE-INDEPENDENT COLOR CONVERTING SECTION
2021
INPUT PROFILE 1 (PERSON SPECTRUM STATISTICAL DATA)
2022
INPUT PROFILE 2 (ANIMAL SPECTRUM STATISTICAL DATA)
202N
INPUT PROFILE N (PLANT SPECTRUM STATISTICAL DATA)
205
IMAGE COMBINING SECTION
203
DEVICE-INDEPENDENT COLOR IMAGE
204 DEVICE VALUE CONVERTING SECTION
2040
OUTPUT PROFILE
OUTPUT IMAGE
300
IMAGE OUTPUT UNIT

FIG. 4

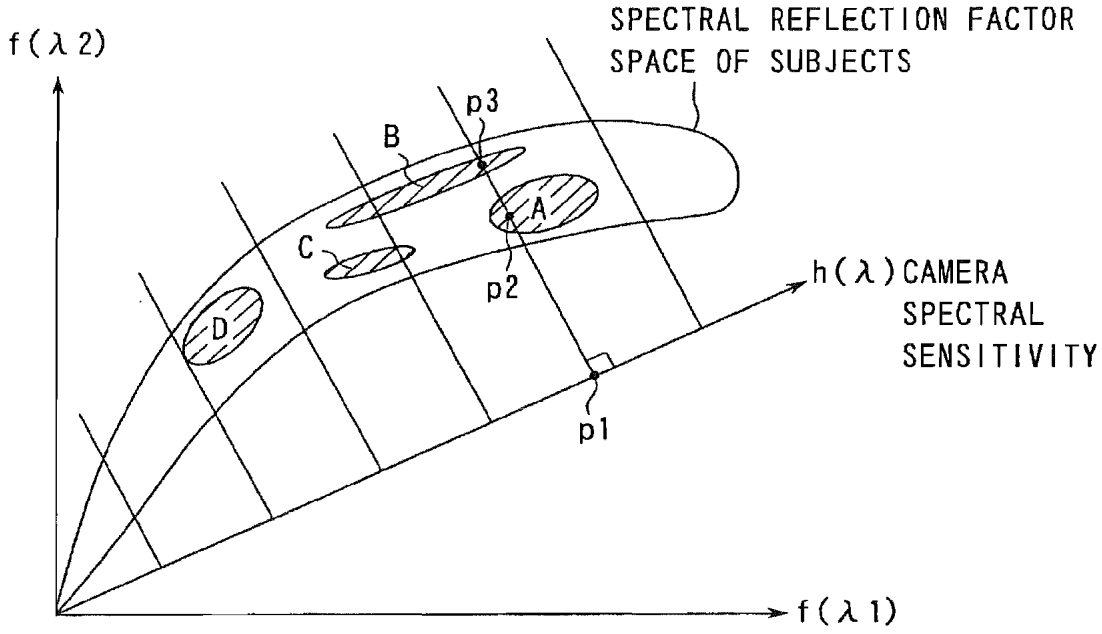

f(λ2)
SPECTRAL REFLECTION FACTOR
SPACE OF SUBJECTS
p3
B
A
C
p2
D
h(λ) CAMERA
SPECTRAL
SENSITIVITY
p1
f(λ1)

FIG. 5

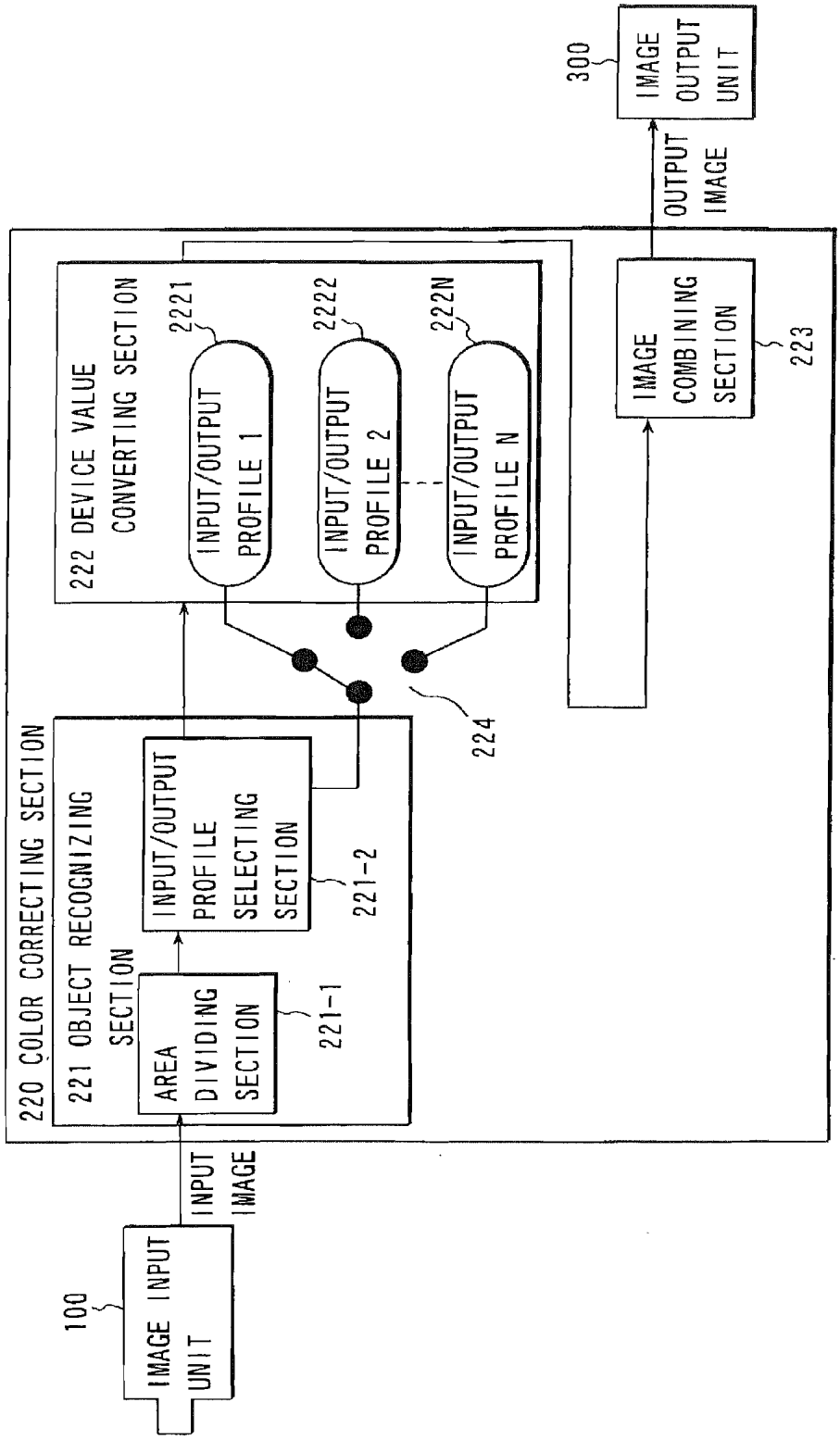

100
IMAGE INPUT UNIT
INPUT IMAGE
220 COLOR CORRECTING SECTION
221 OBJECT RECOGNIZING SECTION
AREA DIVIDING SECTION
221-1
INPUT/OUTPUT PROFILE SELECTING SECTION
221-2
222 DEVICE VALUE CONVERTING SECTION
2221
INPUT/OUTPUT PROFILE 1
2222
INPUT/OUTPUT PROFILE 2
222N
INPUT/OUTPUT PROFILE N
224
IMAGE COMBINING SECTION
223
OUTPUT IMAGE
300
IMAGE OUTPUT UNIT

FIG. 6

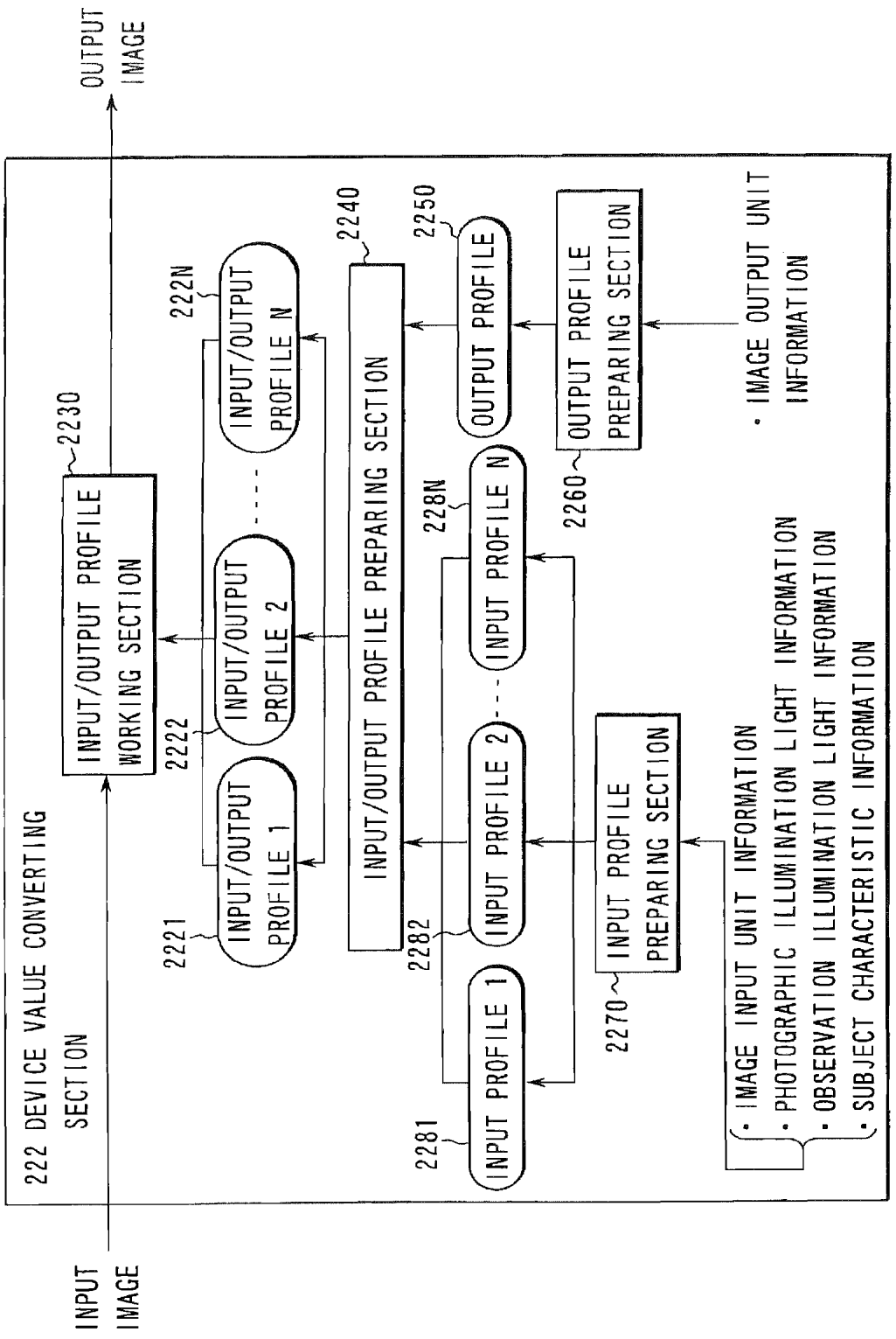

INPUT IMAGE
OUTPUT IMAGE
222 DEVICE VALUE CONVERTING SECTION
INPUT/OUTPUT PROFILE WORKING SECTION
2230
INPUT/OUTPUT PROFILE 1
INPUT/OUTPUT PROFILE 2
INPUT/OUTPUT PROFILE N
2221
2222
222N
INPUT/OUTPUT PROFILE PREPARING SECTION
2240
INPUT PROFILE 1
INPUT PROFILE 2
INPUT PROFILE N
2281
2282
228N
INPUT PROFILE PREPARING SECTION
2270
OUTPUT PROFILE
2250
OUTPUT PROFILE PREPARING SECTION
2260
• IMAGE INPUT UNIT INFORMATION
• PHOTOGRAPHIC ILLUMINATION LIGHT INFORMATION
• OBSERVATION ILLUMINATION LIGHT INFORMATION
• SUBJECT CHARACTERISTIC INFORMATION
• IMAGE OUTPUT UNIT INFORMATION

FIG. 7

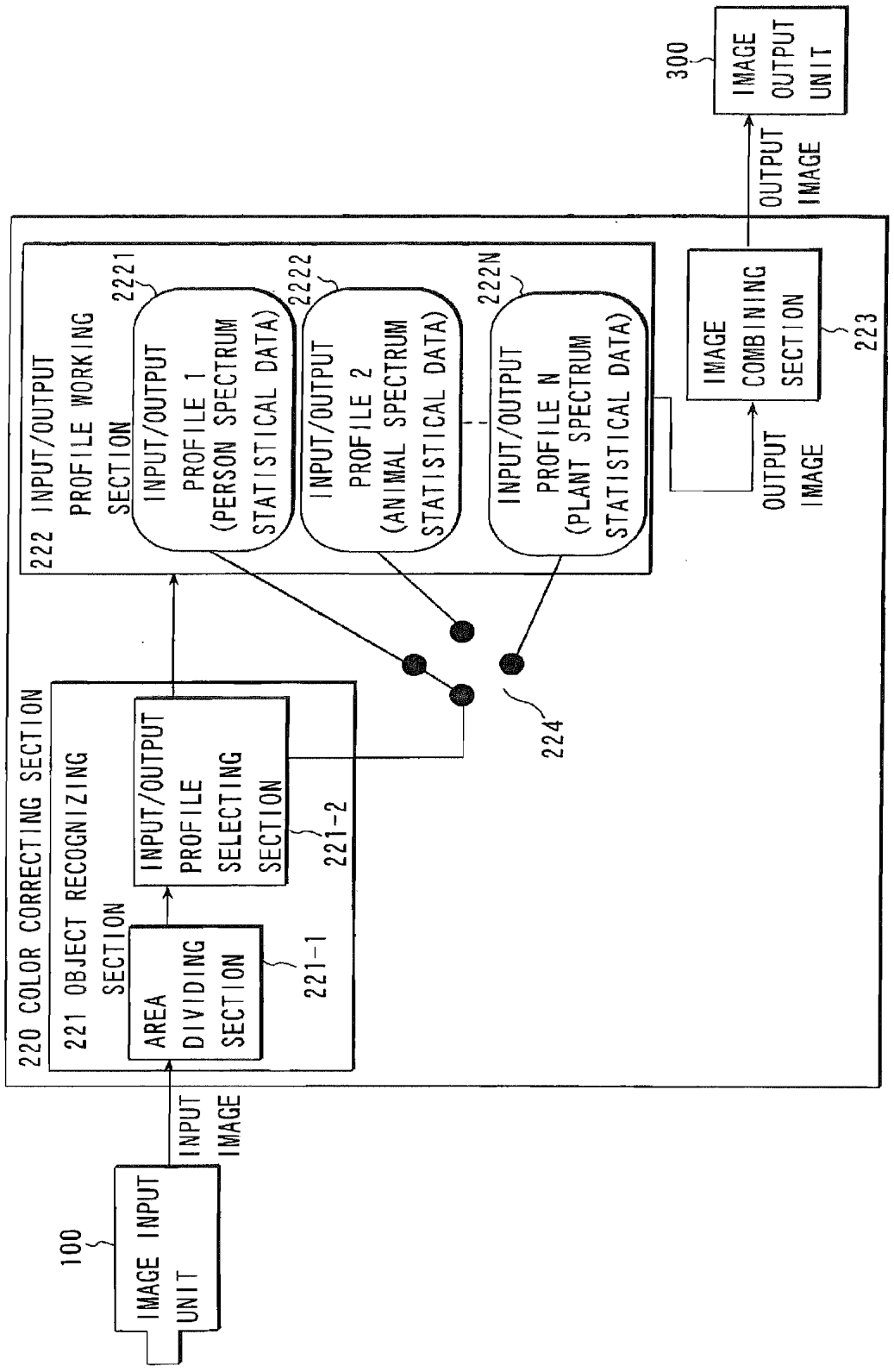

100
IMAGE INPUT UNIT
INPUT IMAGE
220 COLOR CORRECTING SECTION
221 OBJECT RECOGNIZING SECTION
AREA DIVIDING SECTION
221-1
INPUT/OUTPUT PROFILE SELECTING SECTION
221-2
222 INPUT/OUTPUT PROFILE WORKING SECTION
2221
INPUT/OUTPUT PROFILE 1 (PERSON SPECTRUM STATISTICAL DATA)
2222
INPUT/OUTPUT PROFILE 2 (ANIMAL SPECTRUM STATISTICAL DATA)
222N
INPUT/OUTPUT PROFILE N (PLANT SPECTRUM STATISTICAL DATA)
224
IMAGE COMBINING SECTION
223
OUTPUT IMAGE
OUTPUT IMAGE
300
IMAGE OUTPUT UNIT

FIG. 8

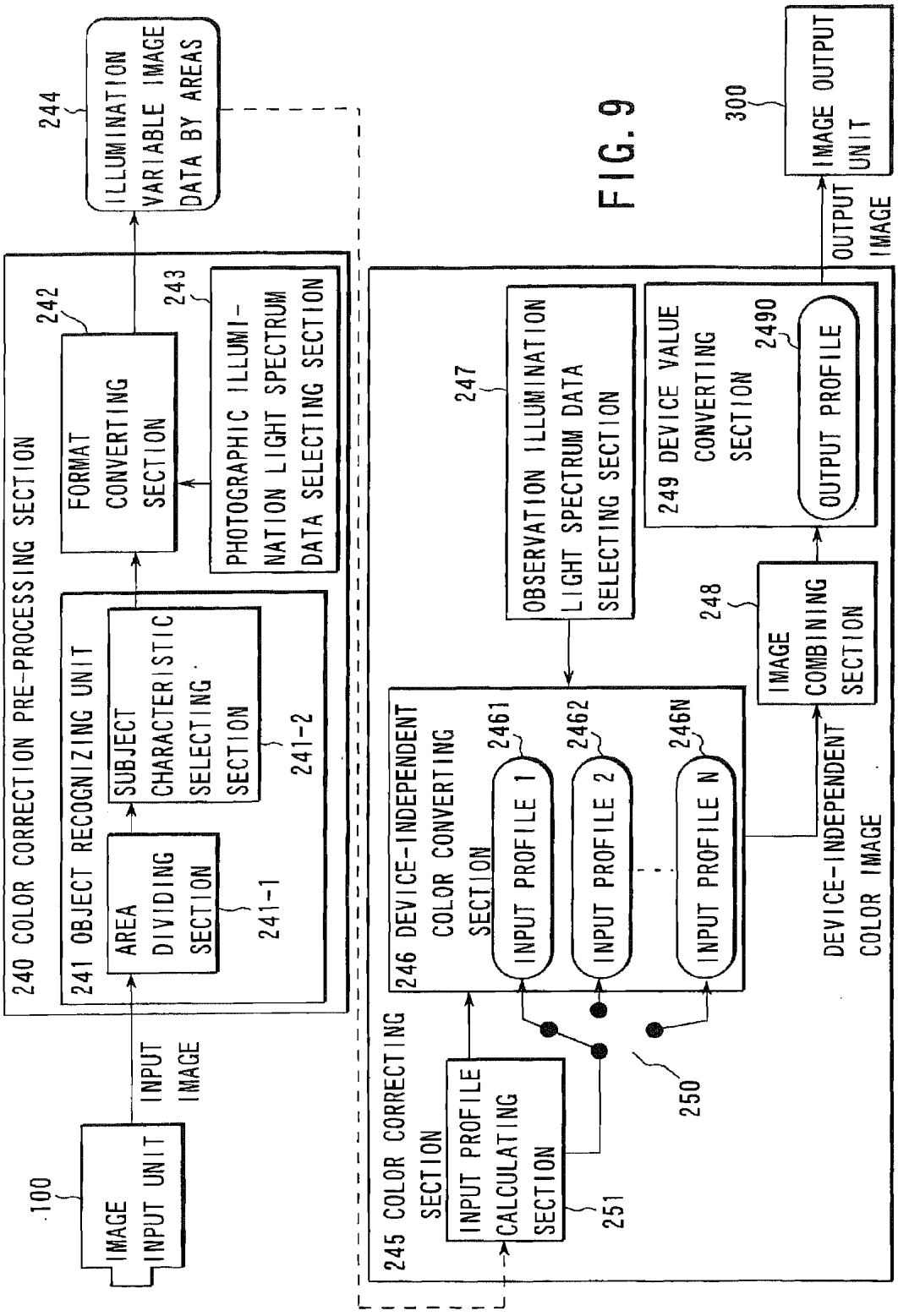

100
IMAGE INPUT UNIT
INPUT IMAGE
240 COLOR CORRECTION PRE-PROCESSING SECTION
241 OBJECT RECOGNIZING UNIT
AREA DIVIDING SECTION
241-1
SUBJECT CHARACTERISTIC SELECTING SECTION
241-2
242
FORMAT CONVERTING SECTION
243
PHOTOGRAPHIC ILLUMINATION LIGHT SPECTRUM DATA SELECTING SECTION
244
ILLUMINATION VARIABLE IMAGE DATA BY AREAS
245 COLOR CORRECTING SECTION
INPUT PROFILE CALCULATING SECTION
251
246 DEVICE-INDEPENDENT COLOR CONVERTING SECTION
INPUT PROFILE 1
2461
INPUT PROFILE 2
2462
INPUT PROFILE N
246N
250
247
OBSERVATION ILLUMINATION LIGHT SPECTRUM DATA SELECTING SECTION
248
IMAGE COMBINING SECTION
249 DEVICE VALUE CONVERTING SECTION
2490
OUTPUT PROFILE
DEVICE-INDEPENDENT COLOR IMAGE
OUTPUT IMAGE
300
IMAGE OUTPUT UNIT

FIG. 9

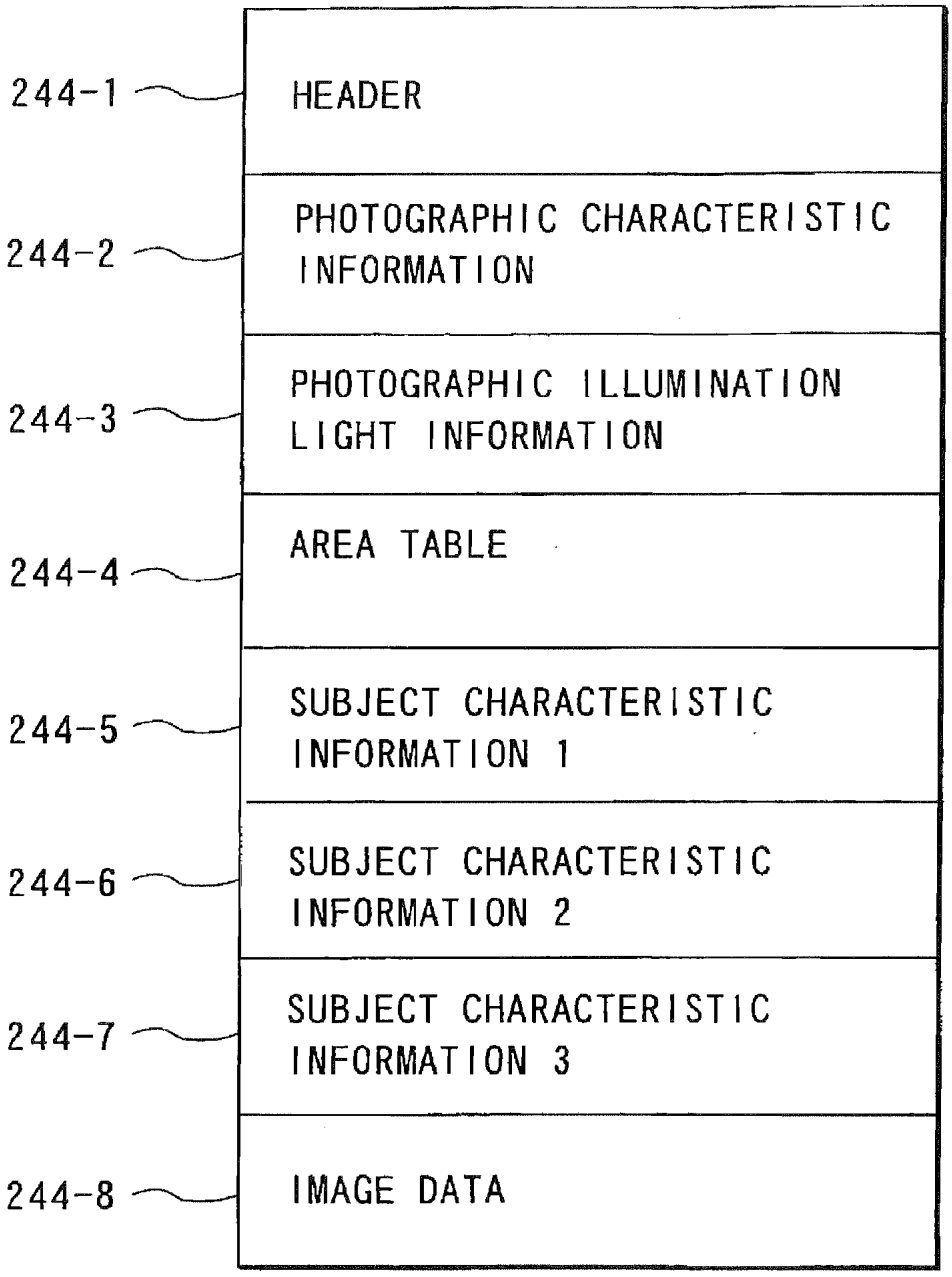

244-1
HEADER
244-2
PHOTOGRAPHIC CHARACTERISTIC INFORMATION
244-3
PHOTOGRAPHIC ILLUMINATION LIGHT INFORMATION
244-4
AREA TABLE
244-5
SUBJECT CHARACTERISTIC INFORMATION 1
244-6
SUBJECT CHARACTERISTIC INFORMATION 2
244-7
SUBJECT CHARACTERISTIC INFORMATION 3
244-8
IMAGE DATA

FIG. 10

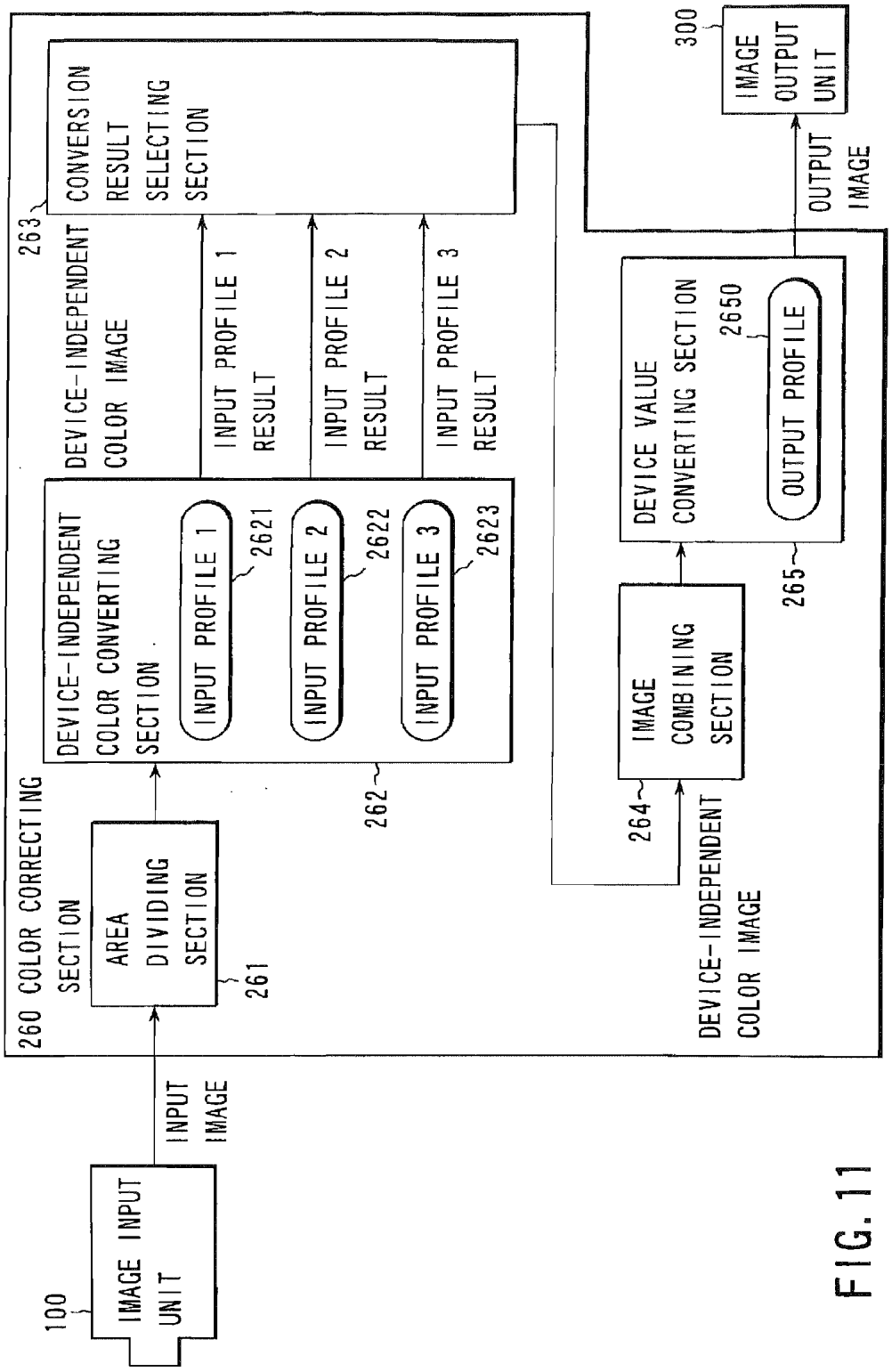

100
IMAGE INPUT UNIT
INPUT IMAGE
260 COLOR CORRECTING SECTION
AREA DIVIDING SECTION
261
DEVICE-INDEPENDENT COLOR CONVERTING SECTION
INPUT PROFILE 1
2621
INPUT PROFILE 2
2622
INPUT PROFILE 3
2623
262
DEVICE-INDEPENDENT COLOR IMAGE
INPUT PROFILE 1 RESULT
INPUT PROFILE 2 RESULT
INPUT PROFILE 3 RESULT
263
CONVERSION RESULT SELECTING SECTION
264
IMAGE COMBINING SECTION
DEVICE VALUE CONVERTING SECTION
2650
OUTPUT PROFILE
265
OUTPUT IMAGE
300
IMAGE OUTPUT UNIT

FIG. 11

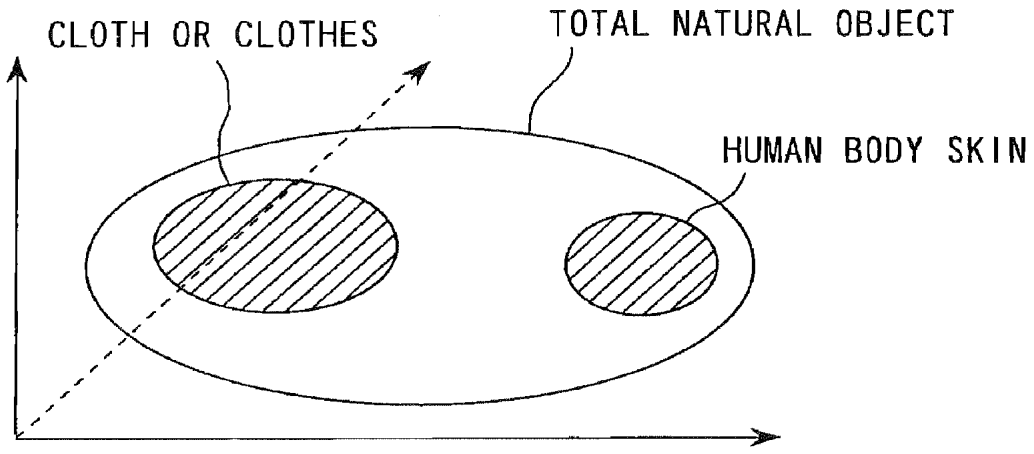


FIG. 12

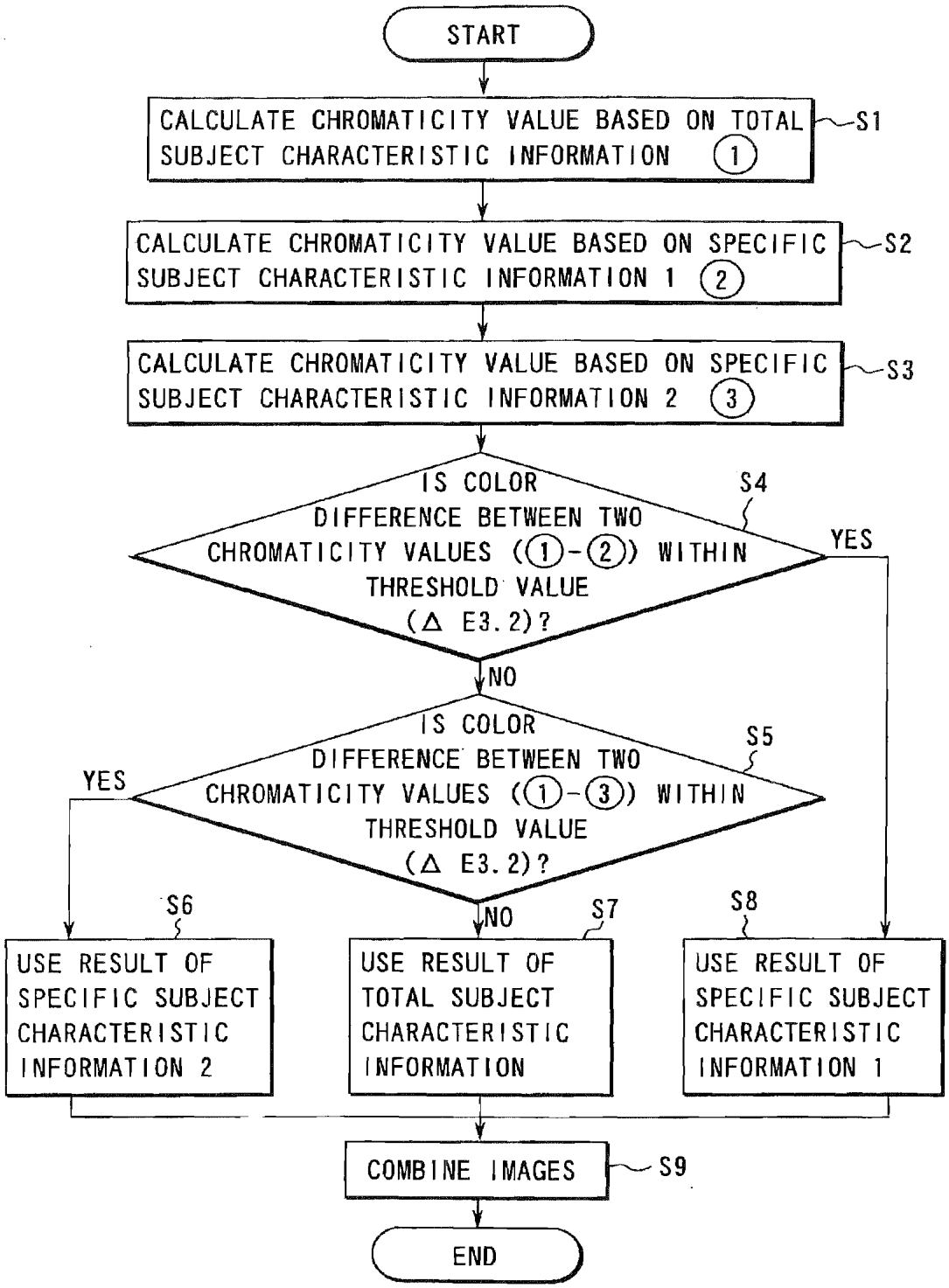

START
CALCULATE CHROMATICITY VALUE BASED ON TOTAL SUBJECT CHARACTERISTIC INFORMATION (1)
S1
CALCULATE CHROMATICITY VALUE BASED ON SPECIFIC SUBJECT CHARACTERISTIC INFORMATION 1 (2)
S2
CALCULATE CHROMATICITY VALUE BASED ON SPECIFIC SUBJECT CHARACTERISTIC INFORMATION 2 (3)
S3
IS COLOR DIFFERENCE BETWEEN TWO CHROMATICITY VALUES ((1)-(2)) WITHIN THRESHOLD VALUE (Δ E3.2)?
S4
YES
NO
IS COLOR DIFFERENCE BETWEEN TWO CHROMATICITY VALUES ((1)-(3)) WITHIN THRESHOLD VALUE (Δ E3.2)?
S5
YES
NO
S6
USE RESULT OF SPECIFIC SUBJECT CHARACTERISTIC INFORMATION 2
S7
USE RESULT OF TOTAL SUBJECT CHARACTERISTIC INFORMATION
S8
USE RESULT OF SPECIFIC SUBJECT CHARACTERISTIC INFORMATION 1
COMBINE IMAGES
S9
END

FIG. 13

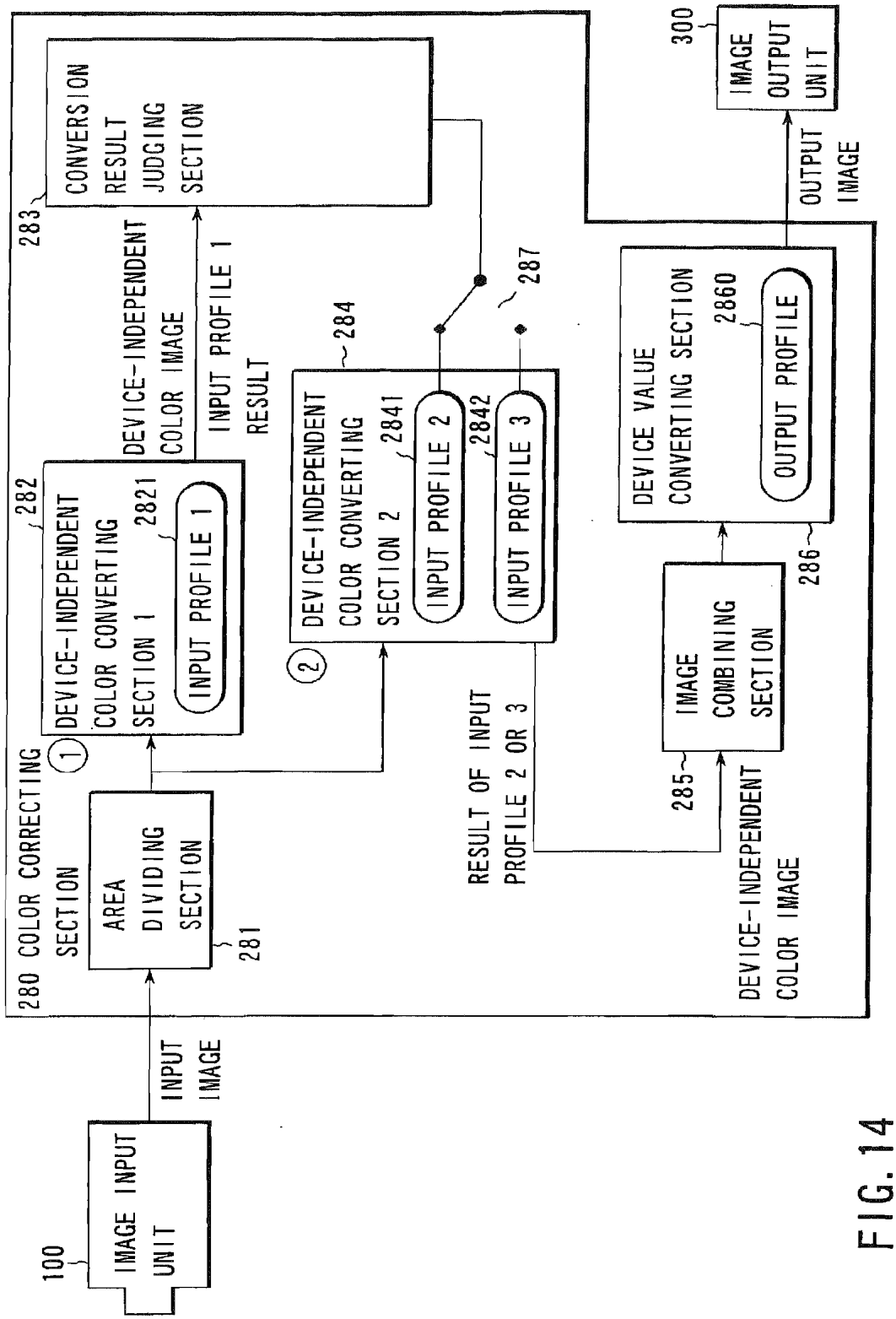

100
IMAGE INPUT UNIT
INPUT IMAGE
280 COLOR CORRECTING SECTION
AREA DIVIDING SECTION
281
282
DEVICE-INDEPENDENT COLOR CONVERTING SECTION 1
2821
INPUT PROFILE 1
283
CONVERSION RESULT JUDGING SECTION
DEVICE-INDEPENDENT COLOR IMAGE
INPUT PROFILE 1 RESULT
284
DEVICE-INDEPENDENT COLOR CONVERTING SECTION 2
2841
INPUT PROFILE 2
2842
INPUT PROFILE 3
287
RESULT OF INPUT PROFILE 2 OR 3
285
IMAGE COMBINING SECTION
DEVICE-INDEPENDENT COLOR IMAGE
286
DEVICE VALUE CONVERTING SECTION
2860
OUTPUT PROFILE
OUTPUT IMAGE
300
IMAGE OUTPUT UNIT

FIG. 14

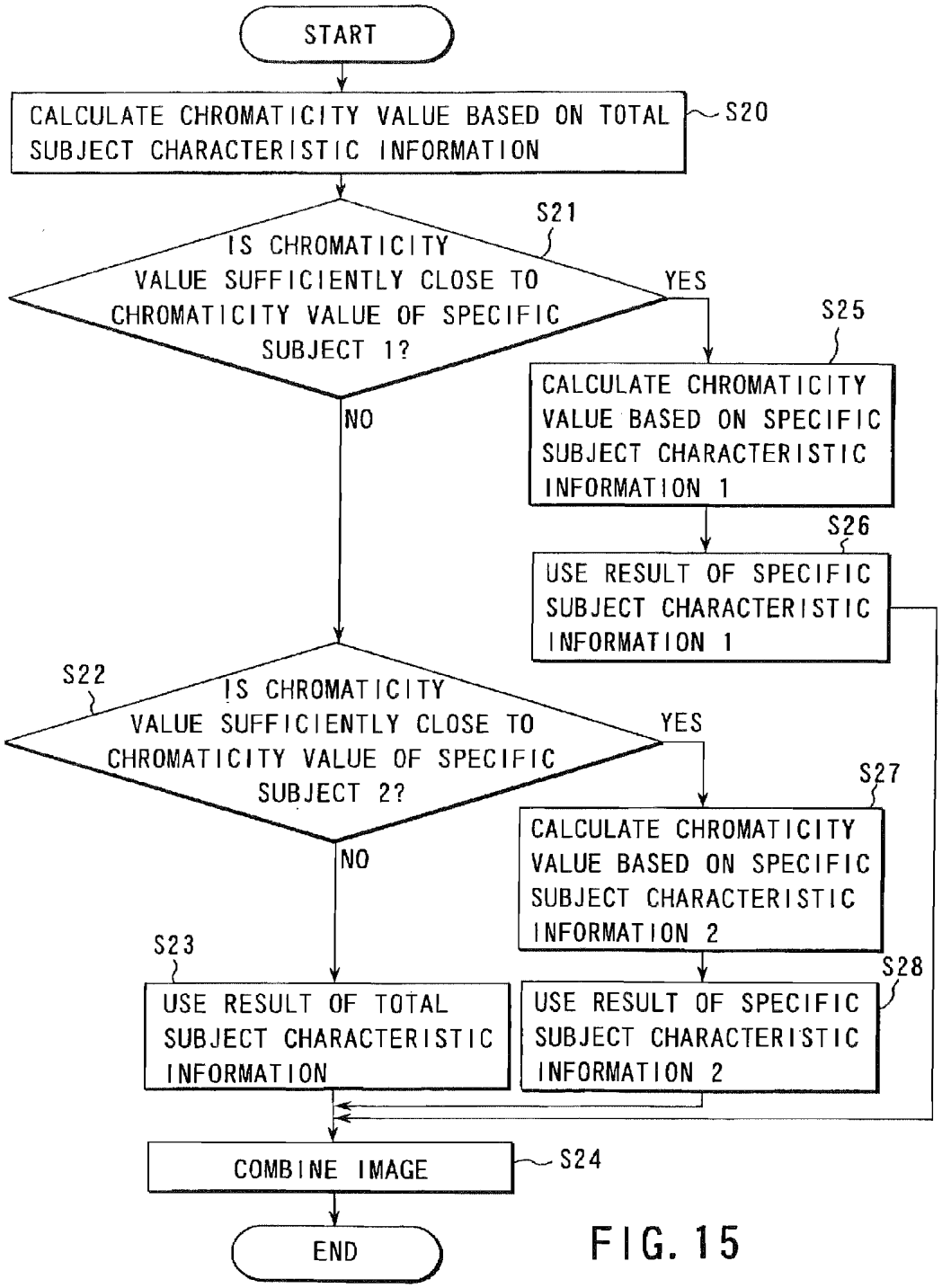

START
CALCULATE CHROMATICITY VALUE BASED ON TOTAL SUBJECT CHARACTERISTIC INFORMATION
S20
S21
IS CHROMATICITY VALUE SUFFICIENTLY CLOSE TO CHROMATICITY VALUE OF SPECIFIC SUBJECT 1?
YES
NO
S25
CALCULATE CHROMATICITY VALUE BASED ON SPECIFIC SUBJECT CHARACTERISTIC INFORMATION 1
S26
USE RESULT OF SPECIFIC SUBJECT CHARACTERISTIC INFORMATION 1
S22
IS CHROMATICITY VALUE SUFFICIENTLY CLOSE TO CHROMATICITY VALUE OF SPECIFIC SUBJECT 2?
YES
NO
S27
CALCULATE CHROMATICITY VALUE BASED ON SPECIFIC SUBJECT CHARACTERISTIC INFORMATION 2
S23
USE RESULT OF TOTAL SUBJECT CHARACTERISTIC INFORMATION
S28
USE RESULT OF SPECIFIC SUBJECT CHARACTERISTIC INFORMATION 2
COMBINE IMAGE
S24
END

FIG. 15

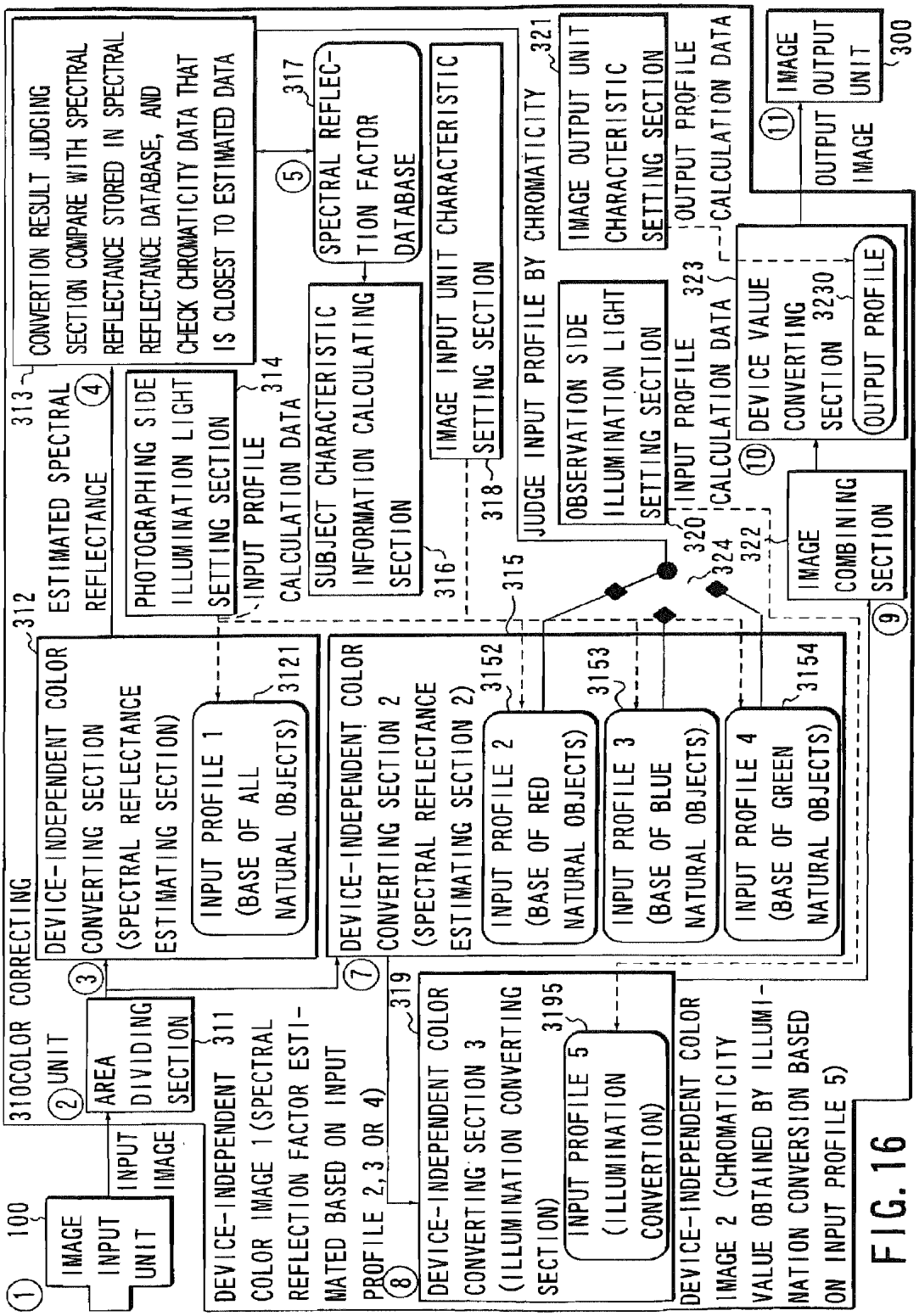

1 100
IMAGE INPUT UNIT
INPUT IMAGE
2 UNIT
AREA DIVIDING SECTION
311
3 CONVERTING SECTION (SPECTRAL REFLECTANCE ESTIMATING SECTION)
310COLOR CORRECTING
312
DEVICE-INDEPENDENT COLOR
ESTIMATED SPECTRAL REFLECTANCE
4
CONVERTION RESULT JUDGING SECTION COMPARE WITH SPECTRAL REFLECTANCE STORED IN SPECTRAL REFLECTANCE DATABASE, AND CHECK CHROMATICITY DATA THAT IS CLOSEST TO ESTIMATED DATA
313
PHOTOGRAPHING SIDE ILLUMINATION LIGHT SETTING SECTION
INPUT PROFILE CALCULATION DATA
314
5
317
SPECTRAL REFLECTION FACTOR DATABASE
SUBJECT CHARACTERISTIC INFORMATION CALCULATING SECTION
316
IMAGE INPUT UNIT CHARACTERISTIC SETTING SECTION
318
315
JUDGE INPUT PROFILE BY CHROMATICITY
321
OBSERVATION SIDE ILLUMINATION LIGHT SETTING SECTION
IMAGE OUTPUT UNIT CHARACTERISTIC SETTING SECTION
INPUT PROFILE
320
323
OUTPUT PROFILE
CALCULATION DATA
324
322
10 DEVICE VALUE CONVERTING SECTION 3230
11 IMAGE OUTPUT UNIT
300
IMAGE COMBINING SECTION
9
OUTPUT PROFILE
DEVICE-INDEPENDENT COLOR CONVERTING SECTION 2 (SPECTRAL REFLECTANCE ESTIMATING SECTION 2)
7
INPUT PROFILE 1 (BASE OF ALL NATURAL OBJECTS)
3121
INPUT PROFILE 2 (BASE OF RED NATURAL OBJECTS)
3152
INPUT PROFILE 3 (BASE OF BLUE NATURAL OBJECTS)
3153
INPUT PROFILE 4 (BASE OF GREEN NATURAL OBJECTS)
3154
DEVICE-INDEPENDENT COLOR CONVERTING SECTION 3 (ILLUMINATION CONVERTING SECTION)
8
319
INPUT PROFILE 5 (ILLUMINATION CONVERTION)
3195
DEVICE-INDEPENDENT COLOR IMAGE 1 (SPECTRAL REFLECTION FACTOR ESTIMATED BASED ON INPUT PROFILE 2, 3 OR 4)
DEVICE-INDEPENDENT COLOR IMAGE 2 (CHROMATICITY VALUE OBTAINED BY ILLUMINATION CONVERSION BASED ON INPUT PROFILE 5)

FIG. 16

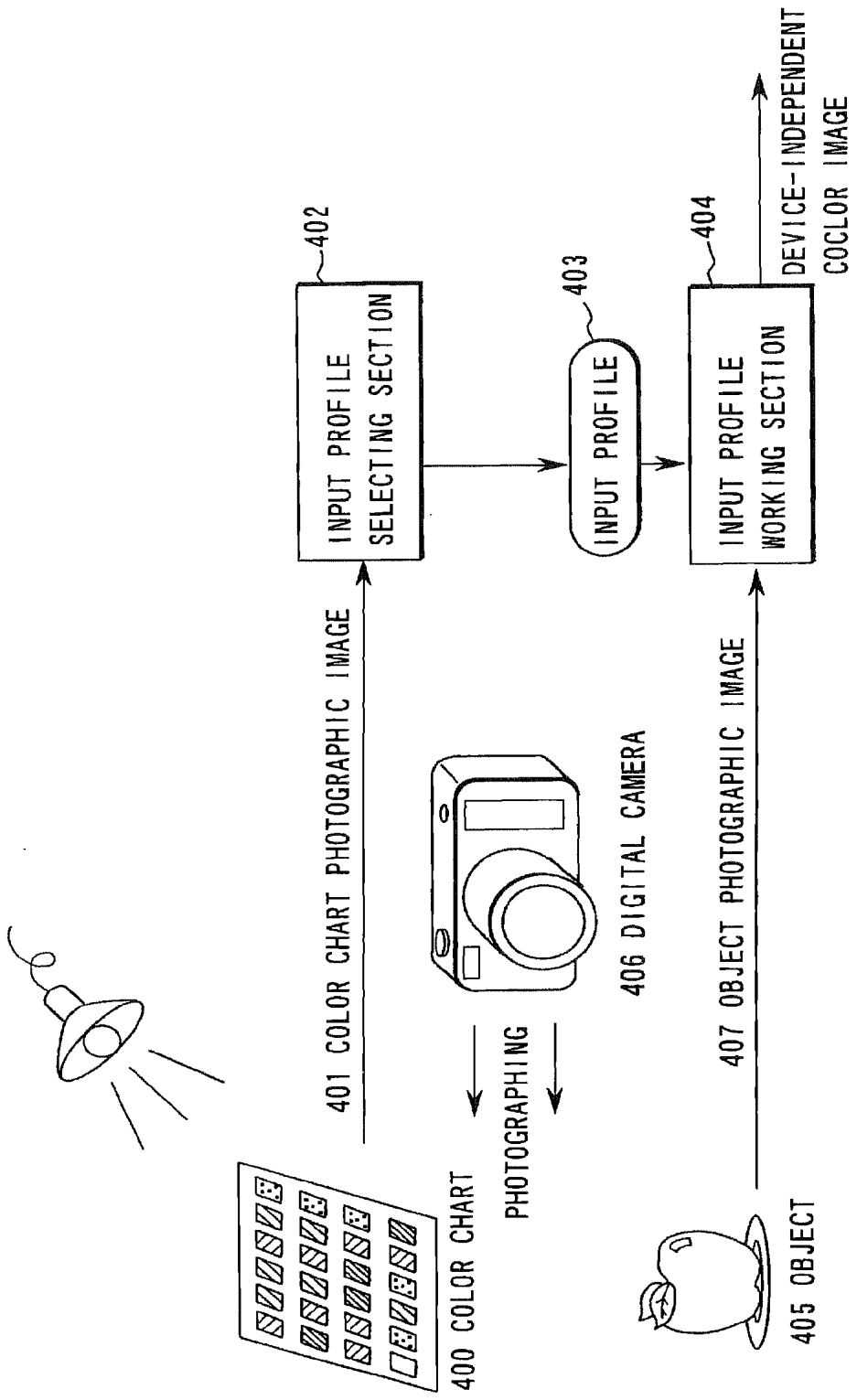

402
INPUT PROFILE SELECTING SECTION
403
INPUT PROFILE
404
INPUT PROFILE WORKING SECTION
DEVICE-INDEPENDENT COCLOR IMAGE
401 COLOR CHART PHOTOGRAPHIC IMAGE
406 DIGITAL CAMERA
PHOTOGRAPHING
407 OBJECT PHOTOGRAPHIC IMAGE
400 COLOR CHART
405 OBJECT

FIG. 17

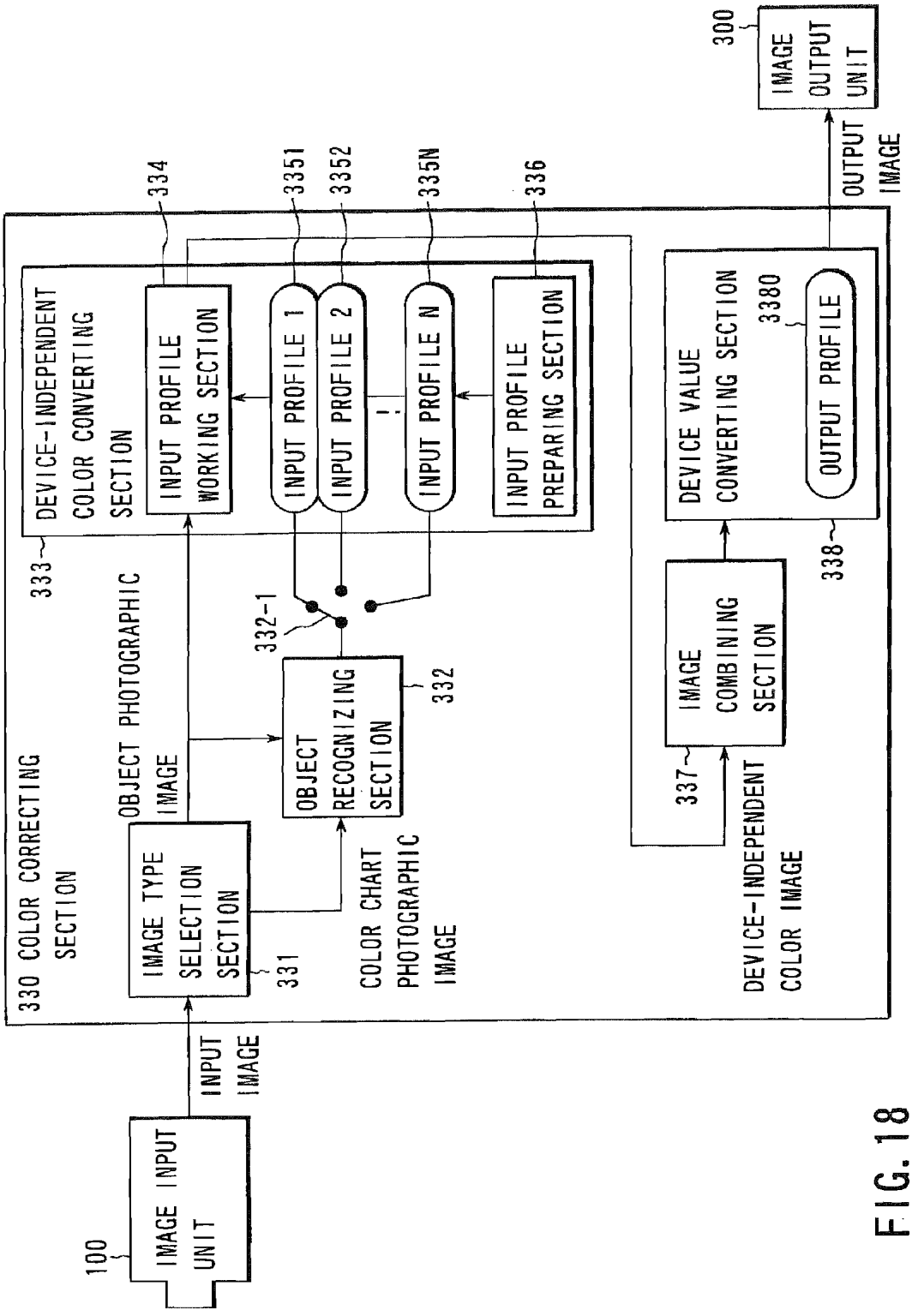

100
IMAGE INPUT UNIT
INPUT IMAGE
330 COLOR CORRECTING SECTION
IMAGE TYPE SELECTION SECTION
331
OBJECT PHOTOGRAPHIC IMAGE
COLOR CHART PHOTOGRAPHIC IMAGE
OBJECT RECOGNIZING SECTION
332
332-1
333
DEVICE-INDEPENDENT COLOR CONVERTING SECTION
334
INPUT PROFILE WORKING SECTION
3351
INPUT PROFILE 1
3352
INPUT PROFILE 2
335N
INPUT PROFILE N
336
INPUT PROFILE PREPARING SECTION
337
IMAGE COMBINING SECTION
DEVICE-INDEPENDENT COLOR IMAGE
338
DEVICE VALUE CONVERTING SECTION
3380
OUTPUT PROFILE
OUTPUT IMAGE
300
IMAGE OUTPUT UNIT

FIG. 18

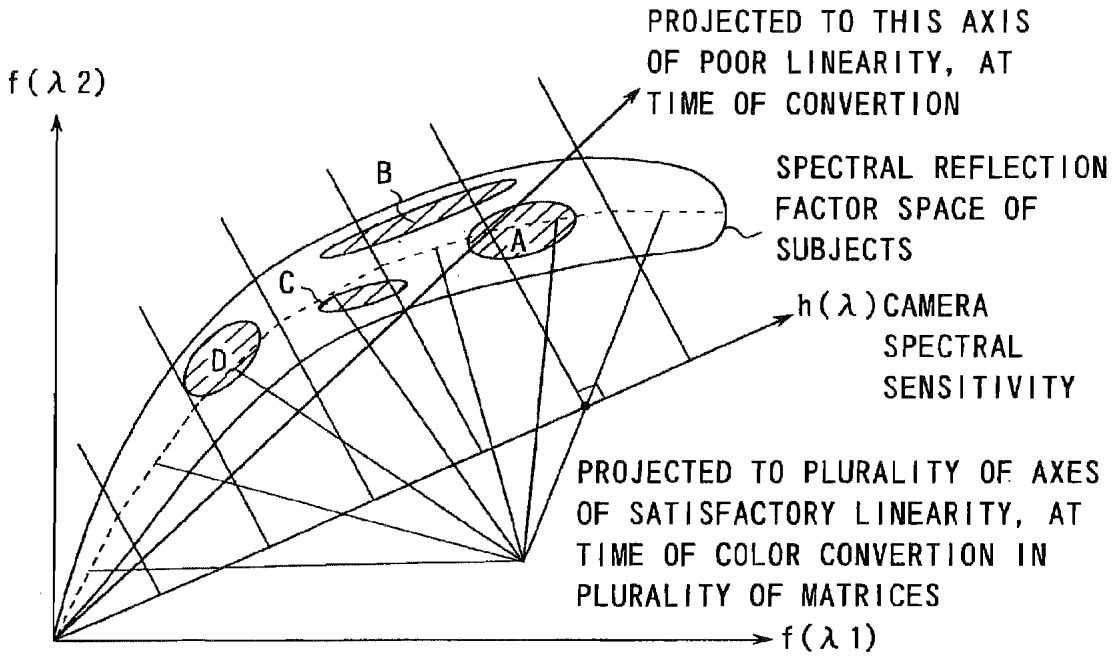

PROJECTED TO THIS AXIS
OF POOR LINEARITY, AT
TIME OF CONVERTION
f(λ2)
B
A
C
D
SPECTRAL REFLECTION
FACTOR SPACE OF
SUBJECTS
h(λ) CAMERA
SPECTRAL
SENSITIVITY
PROJECTED TO PLURALITY OF AXES
OF SATISFACTORY LINEARITY, AT
TIME OF COLOR CONVERTION IN
PLURALITY OF MATRICES
f(λ1)

FIG. 19

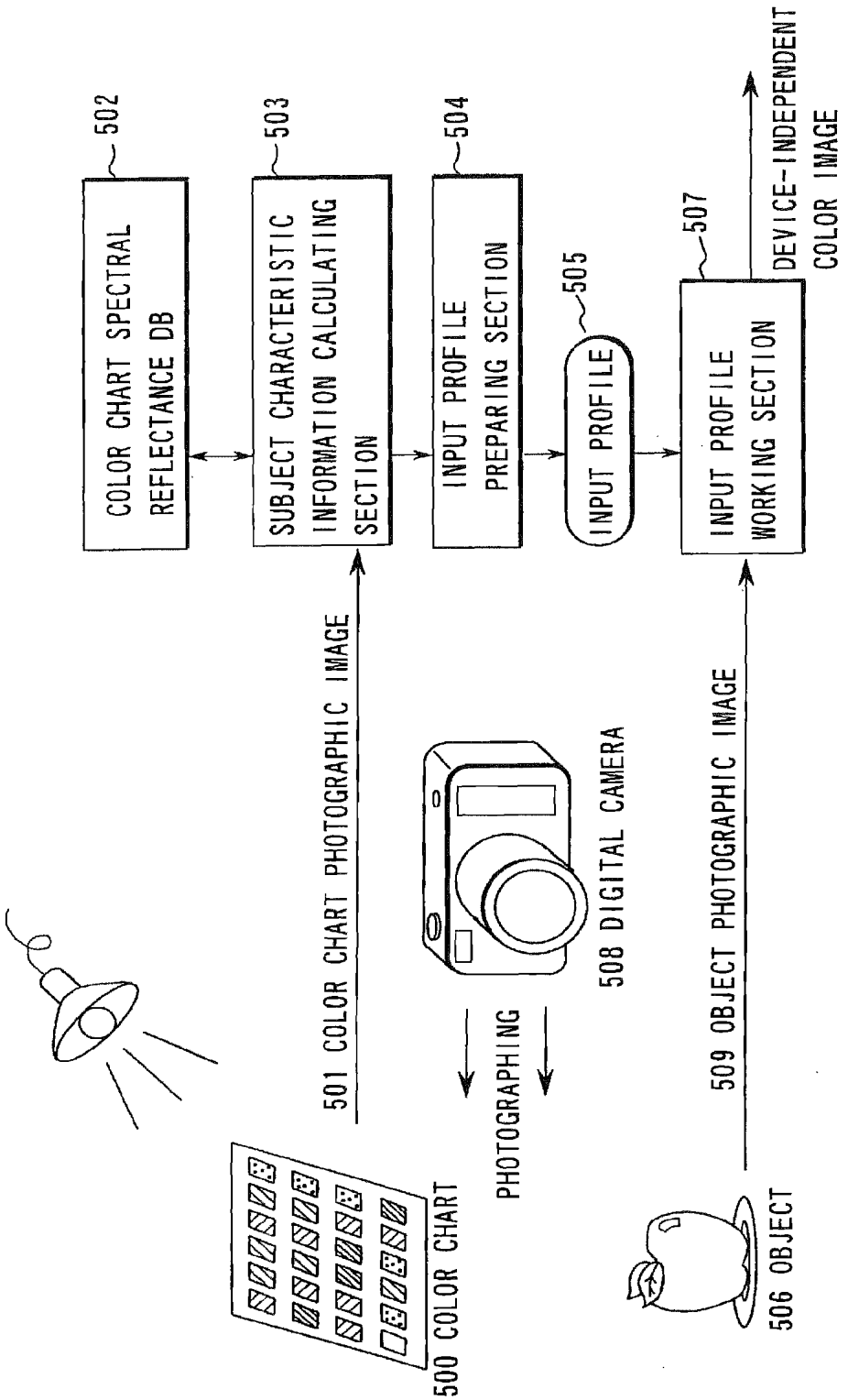

502
COLOR CHART SPECTRAL REFLECTANCE DB
503
SUBJECT CHARACTERISTIC INFORMATION CALCULATING SECTION
504
INPUT PROFILE PREPARING SECTION
505
INPUT PROFILE
507
INPUT PROFILE WORKING SECTION
DEVICE-INDEPENDENT COLOR IMAGE
501 COLOR CHART PHOTOGRAPHIC IMAGE
PHOTOGRAPHING
508 DIGITAL CAMERA
509 OBJECT PHOTOGRAPHIC IMAGE
500 COLOR CHART
506 OBJECT

FIG. 20

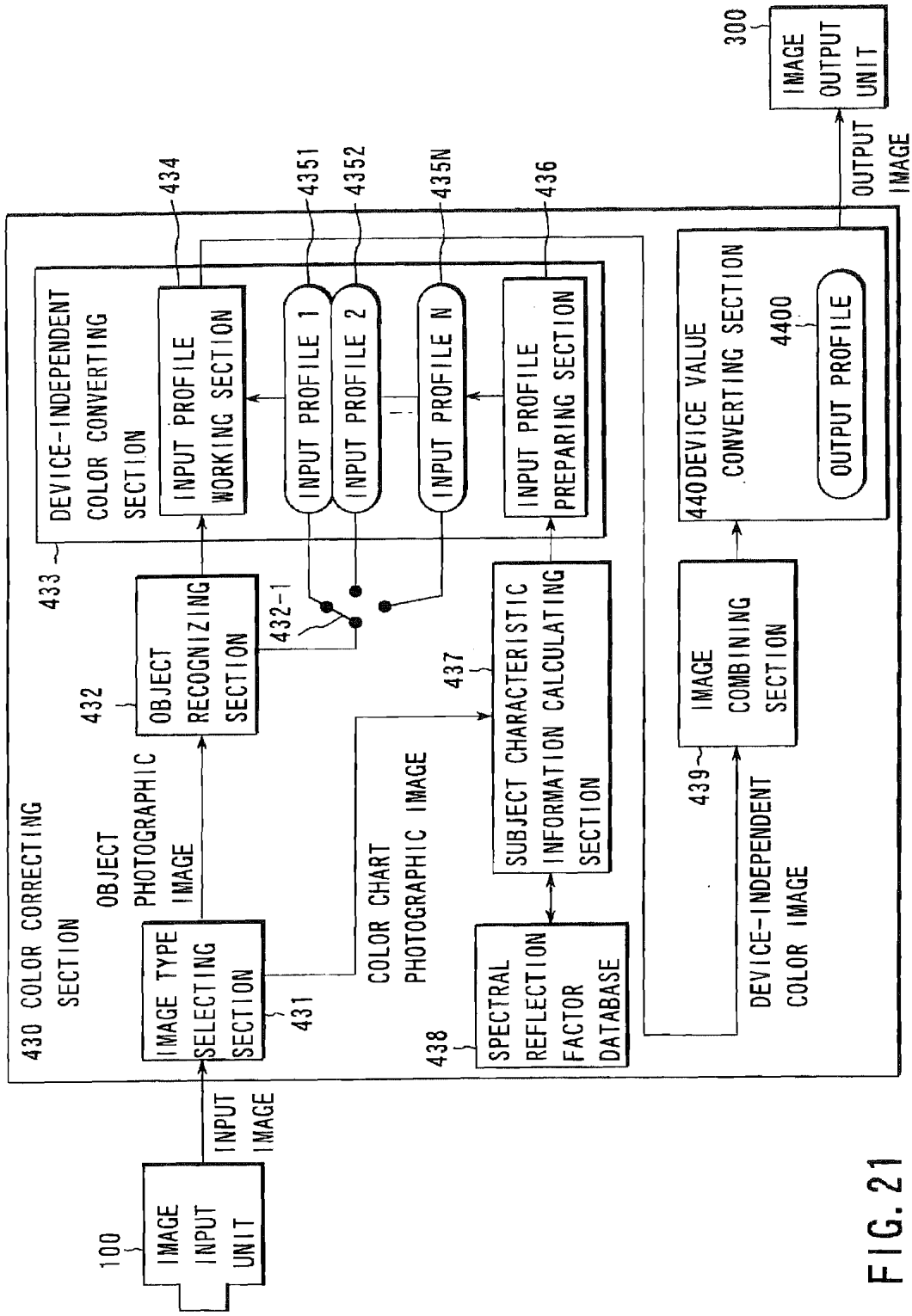

100
IMAGE INPUT UNIT
INPUT IMAGE
430 COLOR CORRECTING SECTION
OBJECT PHOTOGRAPHIC IMAGE
IMAGE TYPE SELECTING SECTION
431
COLOR CHART PHOTOGRAPHIC IMAGE
438
SPECTRAL REFLECTION FACTOR DATABASE
432
OBJECT RECOGNIZING SECTION
432-1
433
DEVICE-INDEPENDENT COLOR CONVERTING SECTION
INPUT PROFILE WORKING SECTION
434
INPUT PROFILE 1
INPUT PROFILE 2
INPUT PROFILE N
4351
4352
435N
437
SUBJECT CHARACTERISTIC INFORMATION CALCULATING SECTION
INPUT PROFILE PREPARING SECTION
436
439
IMAGE COMBINING SECTION
DEVICE-INDEPENDENT COLOR IMAGE
440 DEVICE VALUE CONVERTING SECTION
4400
OUTPUT PROFILE
OUTPUT IMAGE
300
IMAGE OUTPUT UNIT

FIG. 21

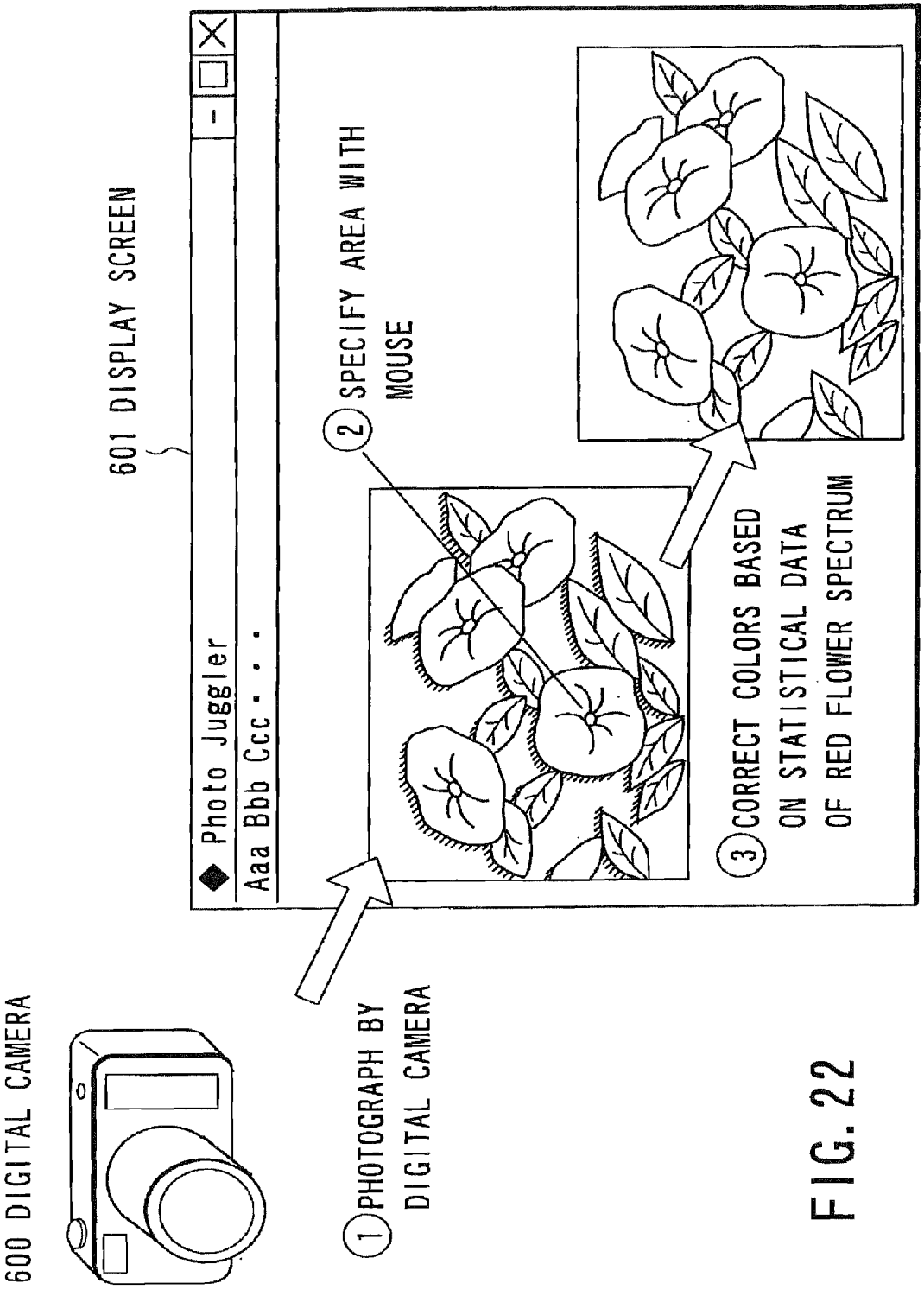

600 DIGITAL CAMERA
601 DISPLAY SCREEN
Photo Juggler
Aaa Bbb Ccc
① PHOTOGRAPH BY DIGITAL CAMERA
② SPECIFY AREA WITH MOUSE
③ CORRECT COLORS BASED ON STATISTICAL DATA OF RED FLOWER SPECTRUM

FIG. 22

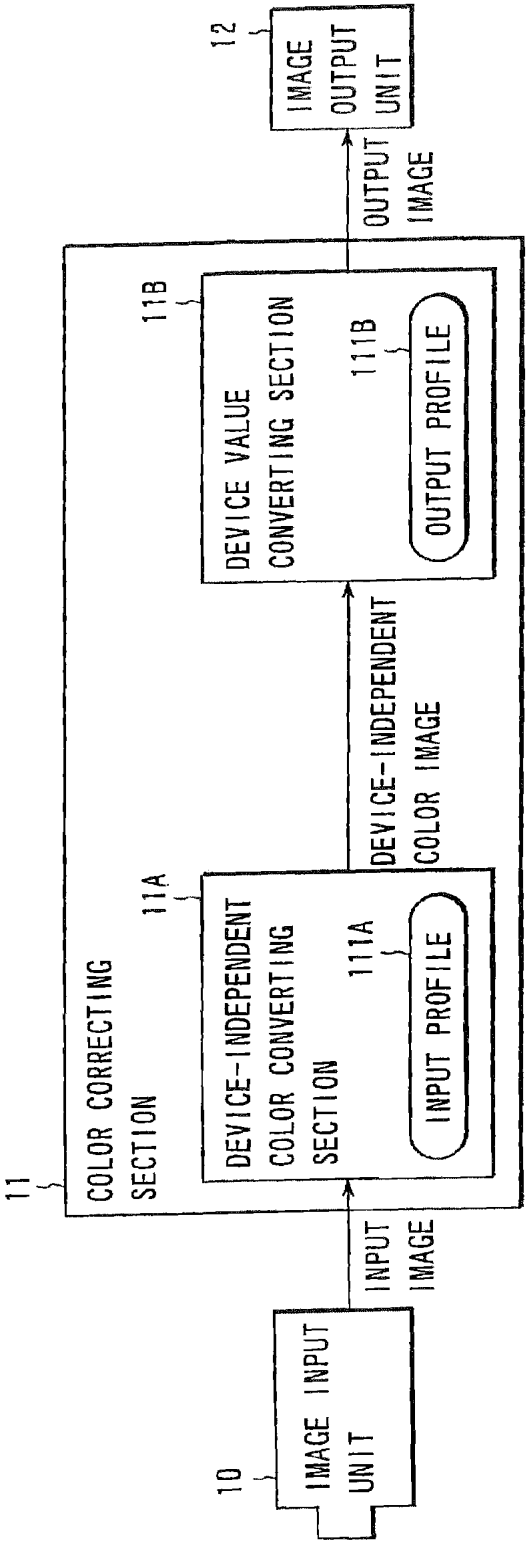


FIG. 23

(Prior Art)

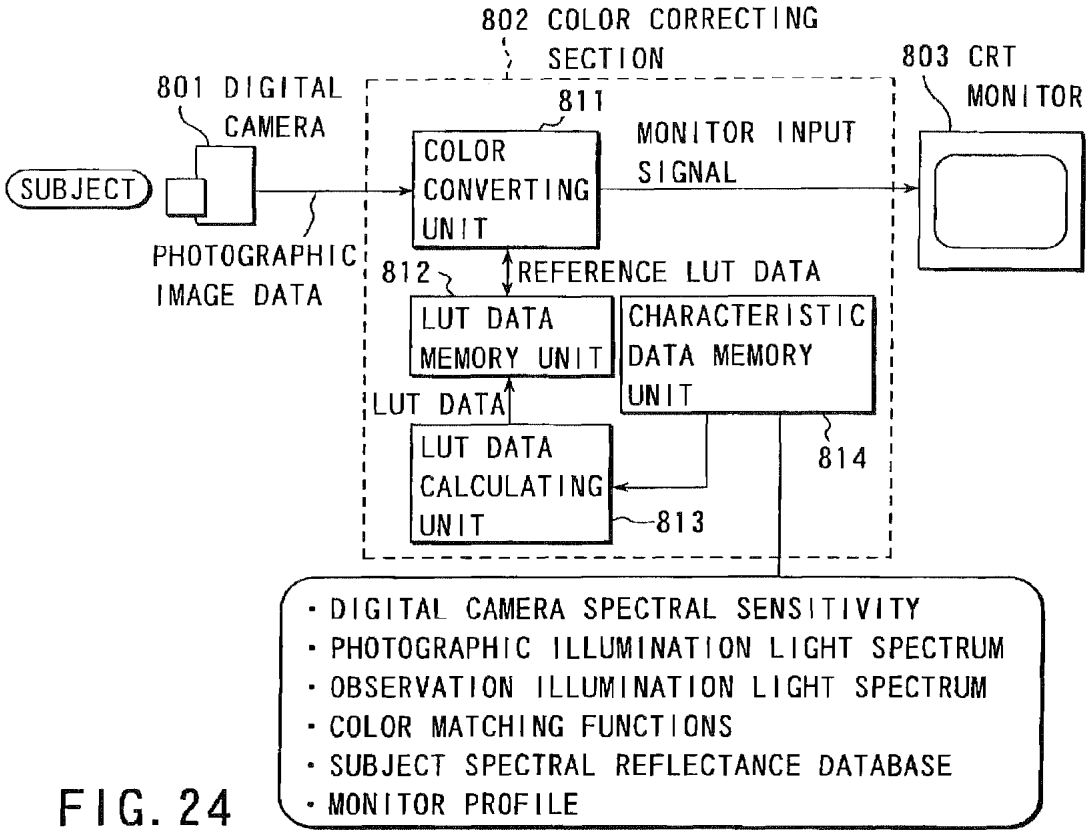


FIG. 24

SUBJECT SPECTRAL REFLECTANCE DATABASE

NUMBER / WAVELENGTH	1	2	. . .	1000
380	0.25	0.52		0.35
381	0.35	0.68		0.58
382	0.38	0.66		0.67
383	0.44	0.53		0.65
.	.	.		.
.	.	.	. . .	.
.	.	.		.
779	0.29	0.85		0.18
780	0.22	0.88		0.15

FIG. 25

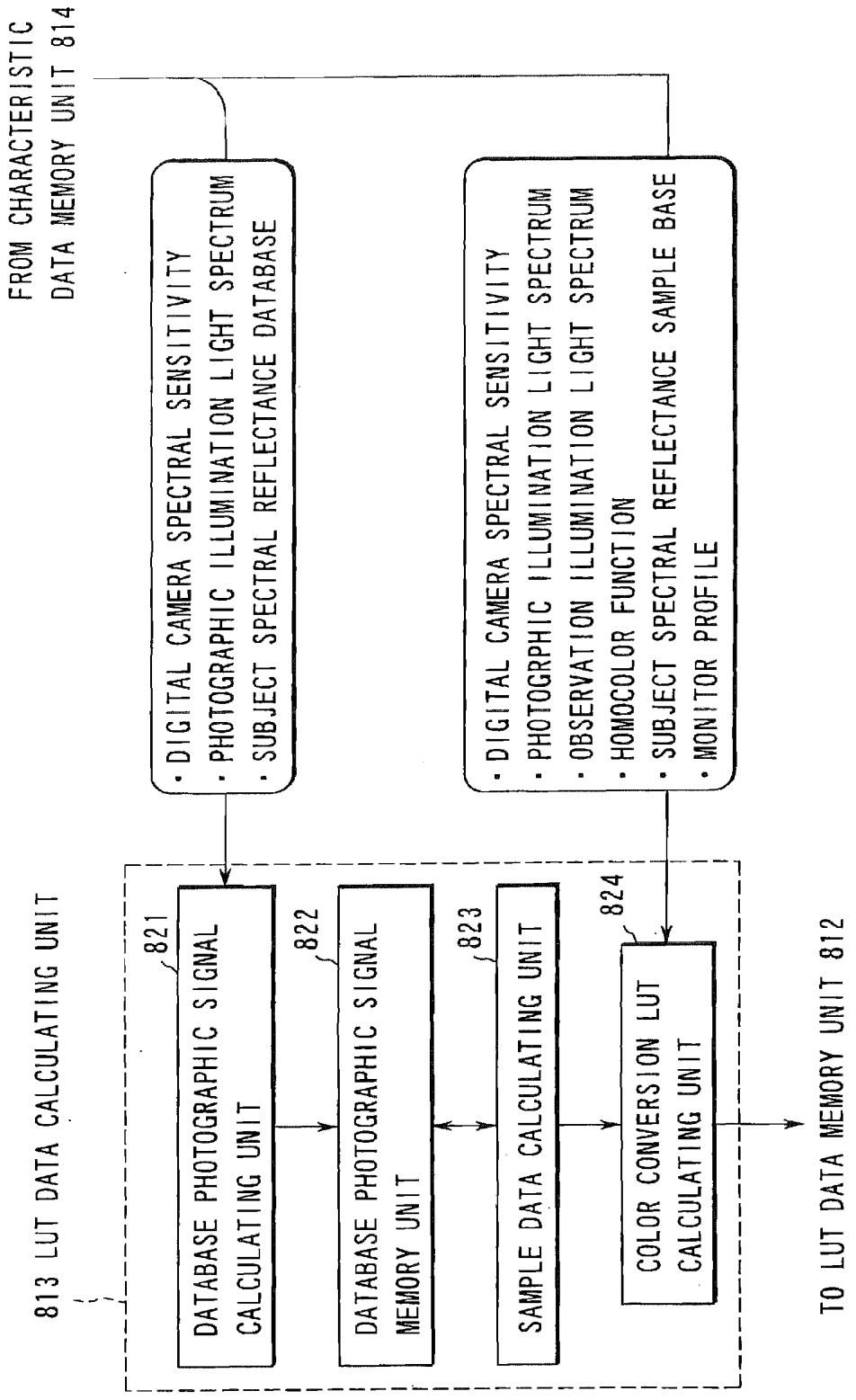

FROM CHARACTERISTIC DATA MEMORY UNIT 814
• DIGITAL CAMERA SPECTRAL SENSITIVITY
• PHOTOGRAPHIC ILLUMINATION LIGHT SPECTRUM
• SUBJECT SPECTRAL REFLECTANCE DATABASE
• DIGITAL CAMERA SPECTRAL SENSITIVITY
• PHOTOGRPHIC ILLUMINATION LIGHT SPECTRUM
• OBSERVATION ILLUMINATION LIGHT SPECTRUM
• HOMOCOLOR FUNCTION
• SUBJECT SPECTRAL REFLECTANCE SAMPLE BASE
• MONITOR PROFILE
813 LUT DATA CALCULATING UNIT
821
DATABASE PHOTOGRAPHIC SIGNAL CALCULATING UNIT
822
DATABASE PHOTOGRAPHIC SIGNAL MEMORY UNIT
823
SAMPLE DATA CALCULATING UNIT
824
COLOR CONVERSION LUT CALCULATING UNIT
TO LUT DATA MEMORY UNIT 812

FIG. 26

DATABASE PHOTOGRAPHIC SIGNAL

NUMBER / CHANNEL	1	2	. . .	1000
R	25	65	. . .	25
G	56	38		13
B	33	121		28

FIG. 27

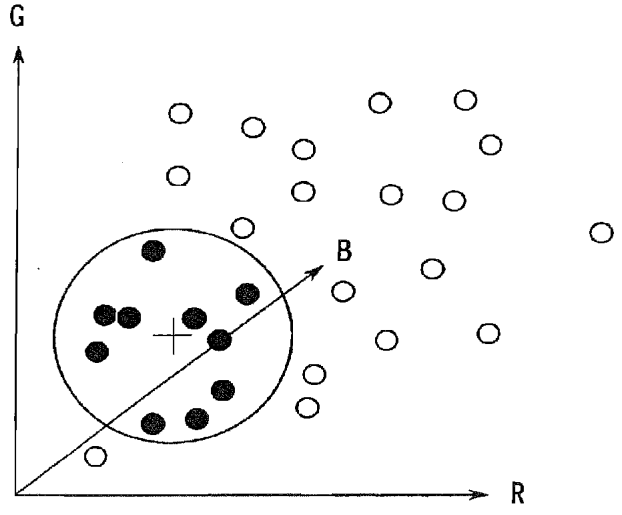


FIG. 28

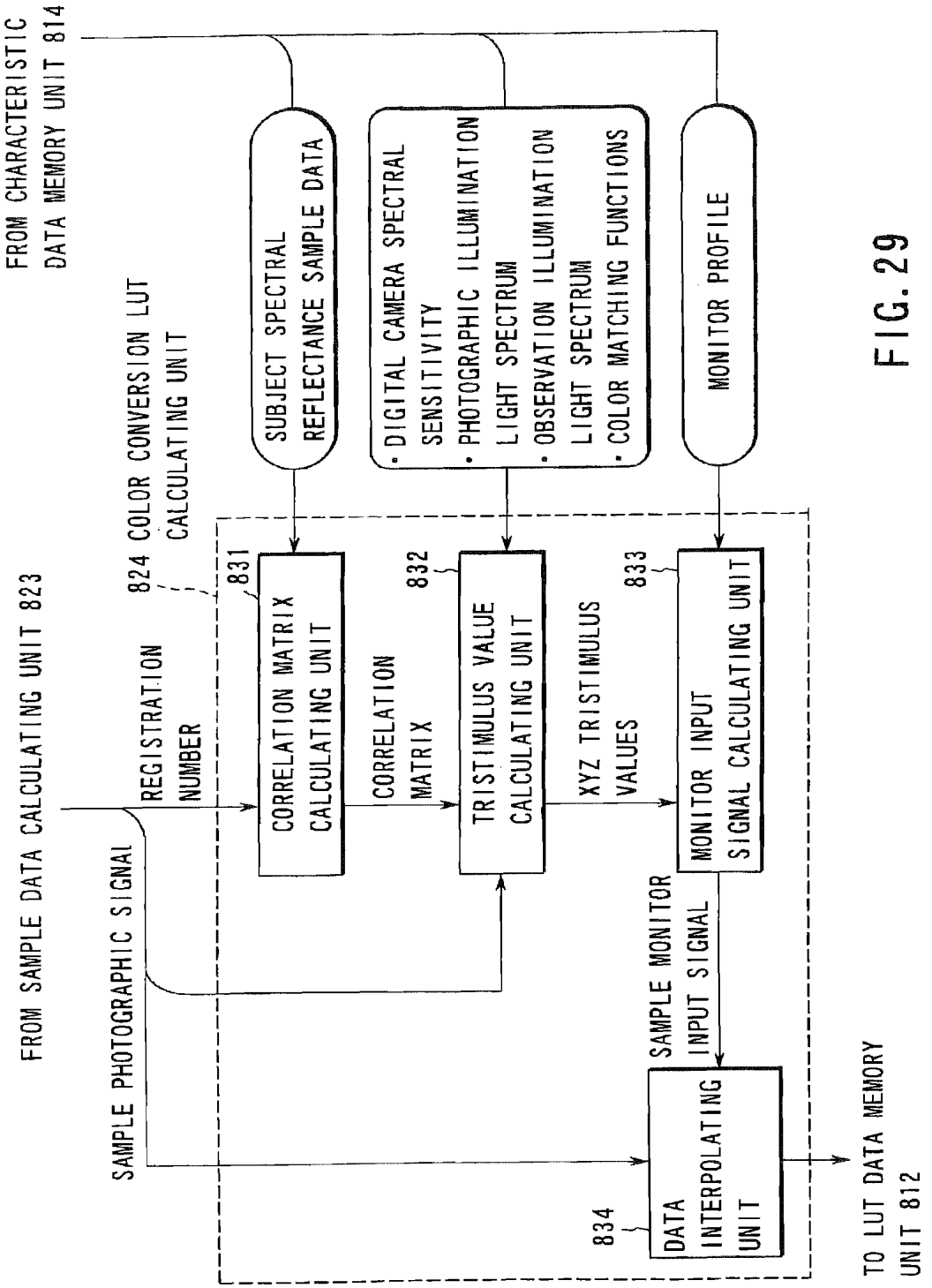

FROM CHARACTERISTIC DATA MEMORY UNIT 814
SUBJECT SPECTRAL REFLECTANCE SAMPLE DATA
• DIGITAL CAMERA SPECTRAL SENSITIVITY
• PHOTOGRAPHIC ILLUMINATION LIGHT SPECTRUM
• OBSERVATION ILLUMINATION LIGHT SPECTRUM
• COLOR MATCHING FUNCTIONS
MONITOR PROFILE
824 COLOR CONVERSION LUT CALCULATING UNIT
831
832
833
FROM SAMPLE DATA CALCULATING UNIT 823
REGISTRATION NUMBER
CORRELATION MATRIX CALCULATING UNIT
CORRELATION MATRIX
TRISTIMULUS VALUE CALCULATING UNIT
XYZ TRISTIMULUS VALUES
MONITOR INPUT SIGNAL CALCULATING UNIT
SAMPLE PHOTOGRAPHIC SIGNAL
SAMPLE MONITOR INPUT SIGNAL
834
DATA INTERPOLATING UNIT
TO LUT DATA MEMORY UNIT 812

FIG. 29

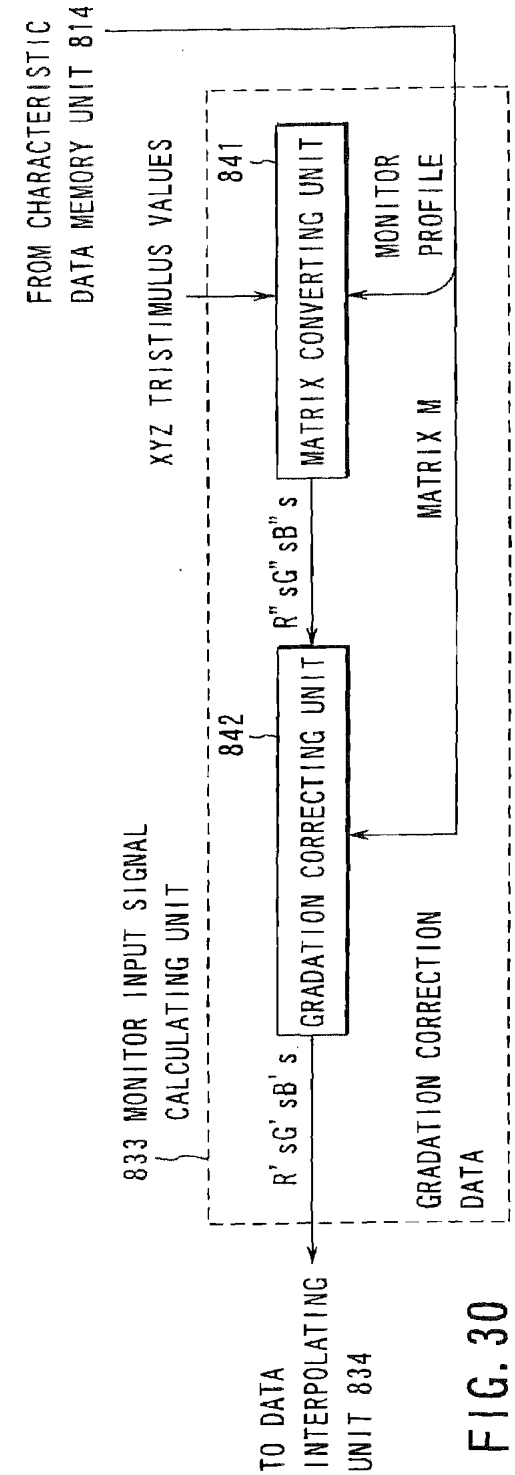

FROM CHARACTERISTIC DATA MEMORY UNIT 814
XYZ TRISTIMULUS VALUES
841
MATRIX CONVERTING UNIT
MONITOR PROFILE
MATRIX M
R" sG" sB" s
842
GRADATION CORRECTING UNIT
R' sG' sB' s
GRADATION CORRECTION DATA
833 MONITOR INPUT SIGNAL CALCULATING UNIT
TO DATA INTERPOLATING UNIT 834

FIG. 30

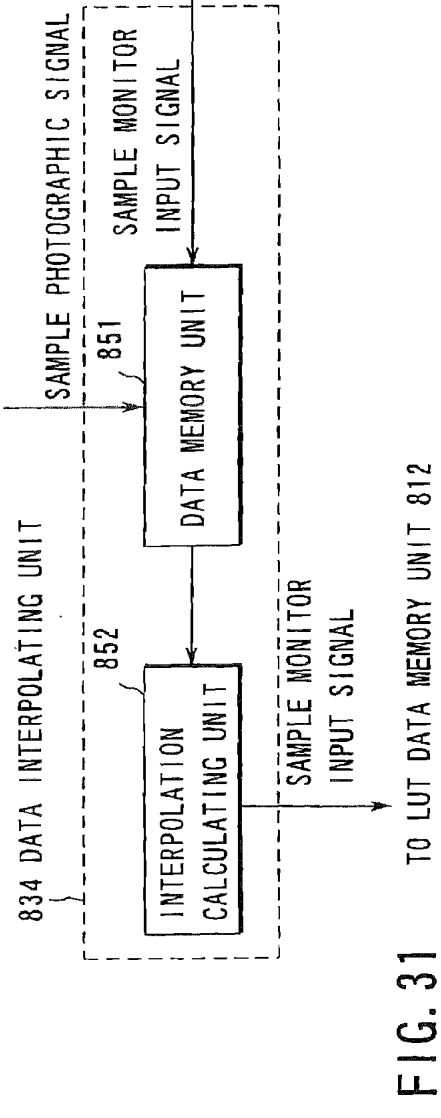

FROM SAMPLE DATA CALCULATING UNIT 823
SAMPLE PHOTOGRAPHIC SIGNAL
851
DATA MEMORY UNIT
SAMPLE MONITOR INPUT SIGNAL
FROM MONITOR INPUT SIGNAL CALCULATING UNIT 833
834 DATA INTERPOLATING UNIT
852
INTERPOLATION CALCULATING UNIT
SAMPLE MONITOR INPUT SIGNAL
TO LUT DATA MEMORY UNIT 812

FIG. 31

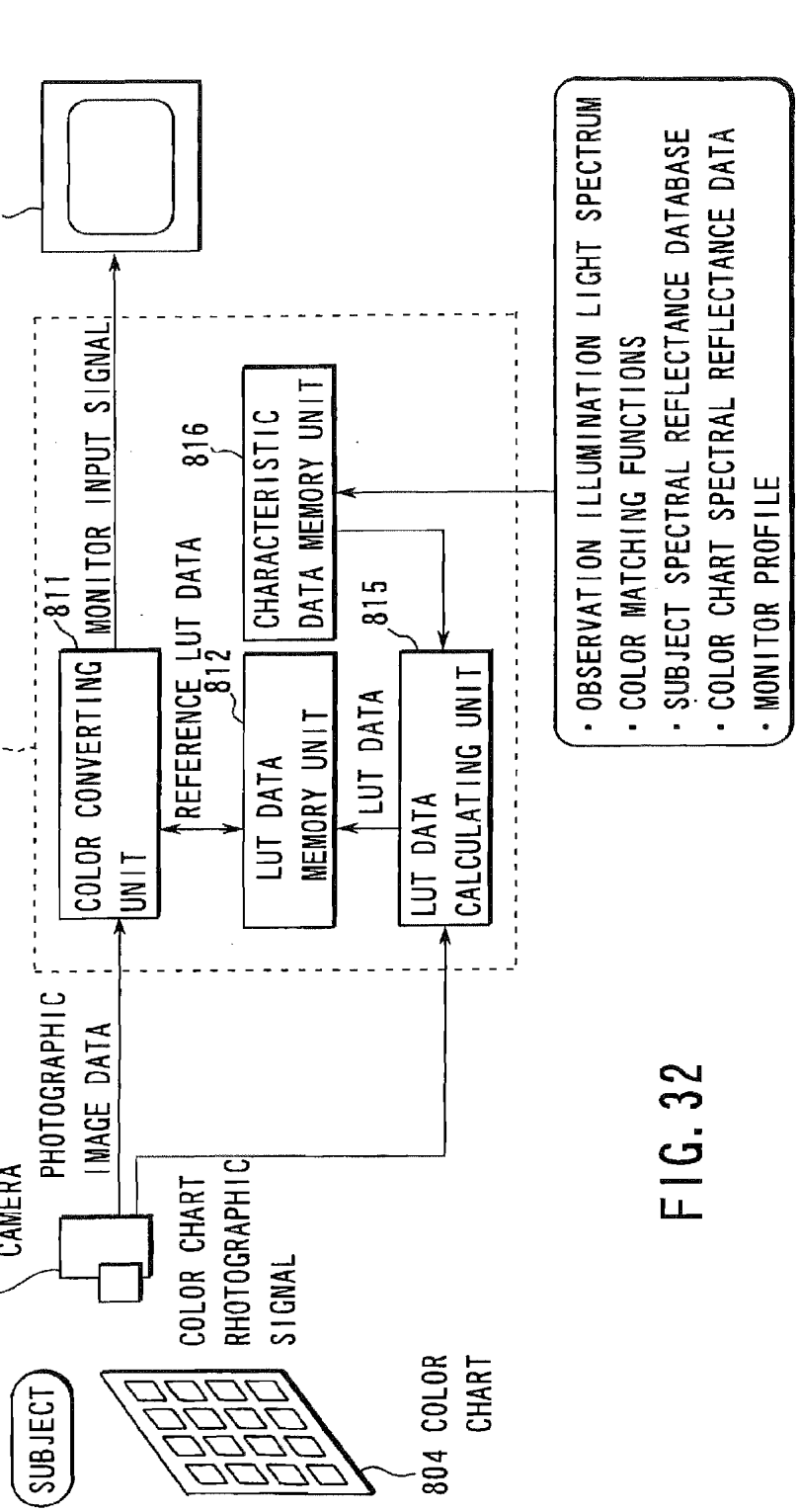

803 CRT MONITOR
802' COLOR CORRECTING SECTION
811
MONITOR INPUT SIGNAL
COLOR CONVERTING UNIT
REFERENCE LUT DATA
812
LUT DATA MEMORY UNIT
816
CHARACTERISTIC DATA MEMORY UNIT
LUT DATA
815
LUT DATA CALCULATING UNIT
• OBSERVATION ILLUMINATION LIGHT SPECTRUM
• COLOR MATCHING FUNCTIONS
• SUBJECT SPECTRAL REFLECTANCE DATABASE
• COLOR CHART SPECTRAL REFLECTANCE DATA
• MONITOR PROFILE
801 DIGITAL CAMERA
PHOTOGRAPHIC IMAGE DATA
COLOR CHART RHOTOGRAPHIC SIGNAL
SUBJECT
804 COLOR CHART

FIG. 32

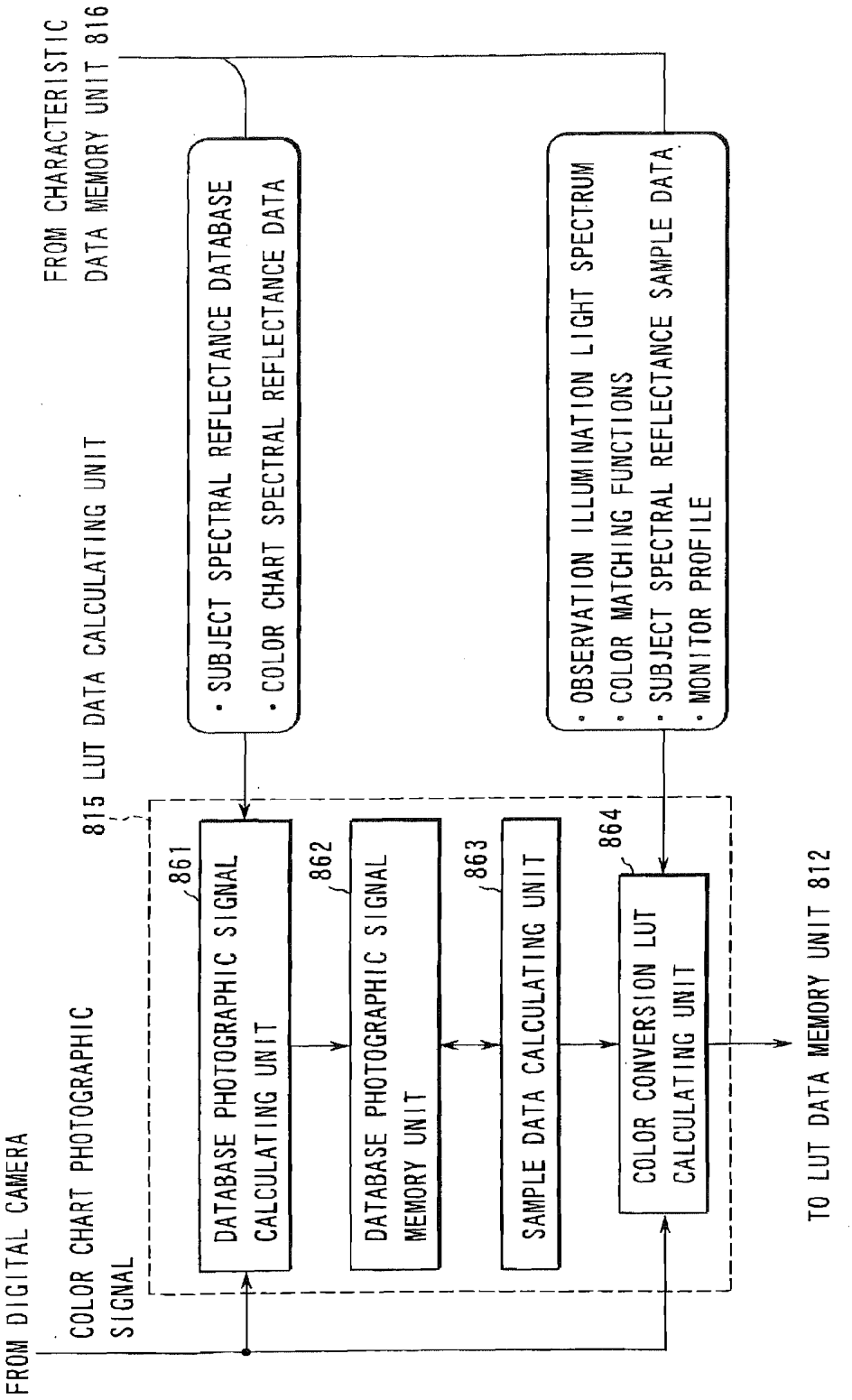

FROM CHARACTERISTIC DATA MEMORY UNIT 816
• SUBJECT SPECTRAL REFLECTANCE DATABASE
• COLOR CHART SPECTRAL REFLECTANCE DATA
• OBSERVATION ILLUMINATION LIGHT SPECTRUM
• COLOR MATCHING FUNCTIONS
• SUBJECT SPECTRAL REFLECTANCE SAMPLE DATA
• MONITOR PROFILE
815 LUT DATA CALCULATING UNIT
861
DATABASE PHOTOGRAPHIC SIGNAL CALCULATING UNIT
862
DATABASE PHOTOGRAPHIC SIGNAL MEMORY UNIT
863
SAMPLE DATA CALCULATING UNIT
864
COLOR CONVERSION LUT CALCULATING UNIT
FROM DIGITAL CAMERA
COLOR CHART PHOTOGRAPHIC SIGNAL
TO LUT DATA MEMORY UNIT 812

FIG. 33

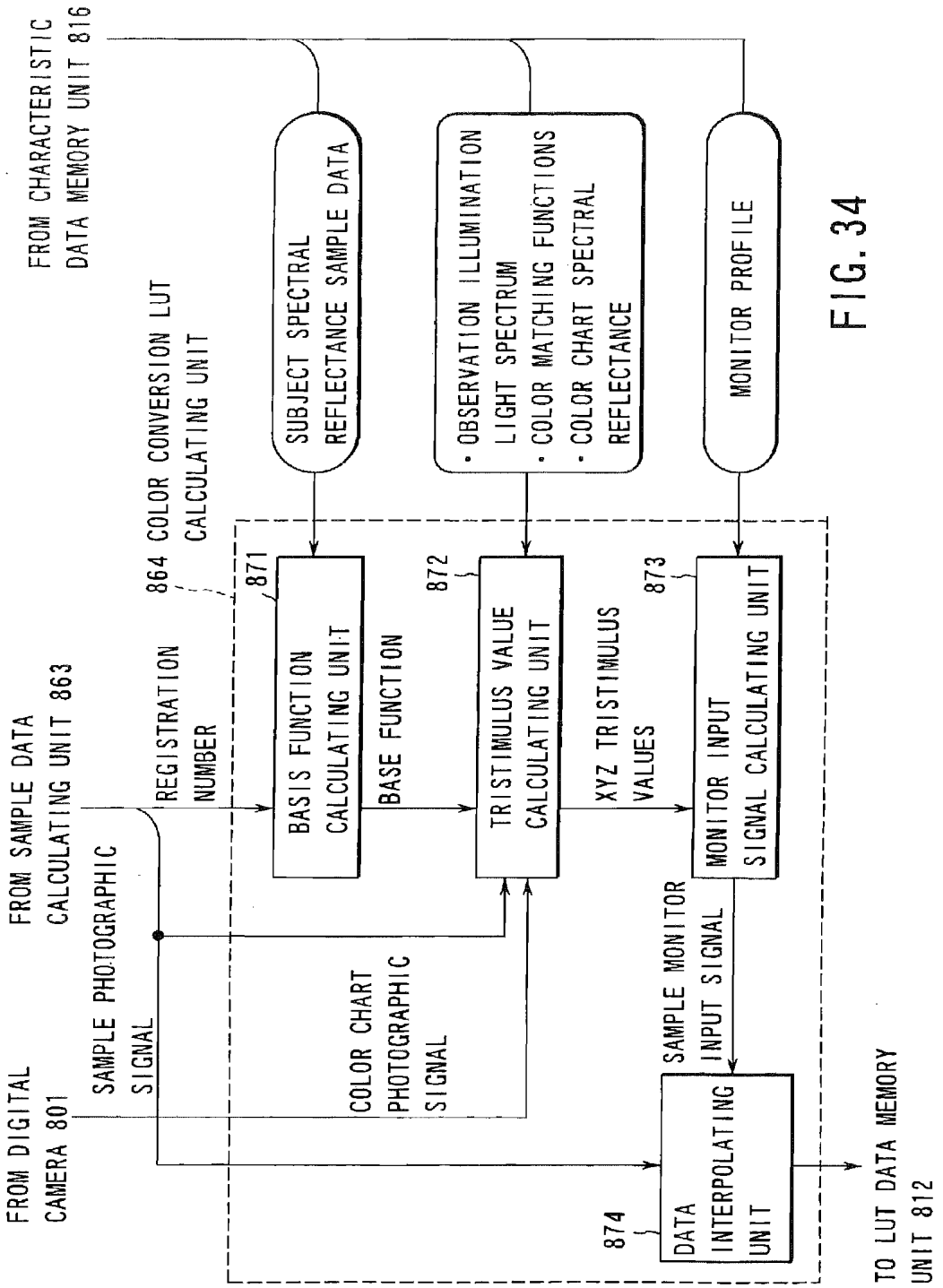

FROM CHARACTERISTIC DATA MEMORY UNIT 816
SUBJECT SPECTRAL REFLECTANCE SAMPLE DATA
• OBSERVATION ILLUMINATION LIGHT SPECTRUM
• COLOR MATCHING FUNCTIONS
• COLOR CHART SPECTRAL REFLECTANCE
MONITOR PROFILE
864 COLOR CONVERSION LUT CALCULATING UNIT
871
872
873
BASIS FUNCTION CALCULATING UNIT
TRISTIMULUS VALUE CALCULATING UNIT
MONITOR INPUT SIGNAL CALCULATING UNIT
FROM SAMPLE DATA CALCULATING UNIT 863
REGISTRATION NUMBER
BASE FUNCTION
XYZ TRISTIMULUS VALUES
SAMPLE PHOTOGRAPHIC SIGNAL
FROM DIGITAL CAMERA 801
COLOR CHART PHOTOGRAPHIC SIGNAL
SAMPLE MONITOR INPUT SIGNAL
874
DATA INTERPOLATING UNIT
TO LUT DATA MEMORY UNIT 812

FIG. 34

COLOR REPRODUCTION SYSTEM FOR CARRYING OUT COLOR CORRECTION BY CHANGING OVER COLOR CORRECTION PARAMETERS ACCORDING TO IMAGES OF PHOTOGRAPHED SUBJECTS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from the prior Japanese Patent Applications No. 11-151969, filed May 31, 1999; and No. 11-172772, filed Jun. 18, 1999, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

The present invention relates to a color reproduction system having a color image processing unit for estimating colors of a photographed subject from photographic signals obtained by photographing the subject by a color photographing unit such as a digital camera or the like.

As a method of estimating color information on a photographed subject under a predetermined illumination light from color-image data obtained by photographing the subject by a color photographing unit such as a digital camera or the like, there has been proposed a method of using foresight information on the photographed subject such as a base function or a correlation matrix of a spectral reflectance of the subject, as disclosed in Japanese Patent Application KOKAI Publication No. 11-85952. When a base function or a correlation matrix of a spectral reflectance of the subject is used, it is possible to estimate colors of the subject in high precision and reproduce the colors even if a photographic illumination light at the time of the photographing is different from an observation illumination light at the time of an observation.

This conventional color reproduction system uses a spectral sensitivity of a color photographing unit, a photographic illumination light spectrum and an observation illumination light spectrum as information for estimating colors. However, these data have conventionally been obtained by measurement using an expensive measuring instrument such as a spectrometer. Therefore, it has not been possible to provide a simple color reproduction system.

On the other hand, in Jpn. Pat. Appln. KOKAI Publication No. 11-96333, there has been disclosed another method of utilizing a photographic signal of an object such as color charts of known spectral reflectances obtained by photographing the object at the same time as the photographing of a subject or under the same photographing conditions. This method is for estimating color information of the photographed subject under a predetermined illumination light by utilizing the object photographic signal, without using the spectral sensitivity of the color photographing unit or measurement data of the photographic illumination light spectrum. According to this method, it is not necessary to measure in advance the spectral sensitivity of a color-photographing unit. It is not necessary to measure a photographic illumination light spectrum at the time of photographing, either. Therefore, this method can simplify the system.

For example, it is possible to arrange as follows. At a hospital A, a face of a patient is photographed in colors by a digital camera, and at the same time, a predetermined color chart is photographed. The image data of these photographs are transferred to a hospital B. At the hospital B, the face colors of the patient are converted into face colors of the patient under the observation illumination light at the hospital B, and the converted face colors are displayed on the monitor. When this system is employed, an expensive measuring instrument like a spectrometer is not necessary at the hospital A where the picture is taken. Thus, it becomes easy to obtain the data for accurate reproduction of colors.

In the above-described color reproduction system for converting illumination colors by using the foresight information of a subject, it is essential that the color photographing unit has independent spectral sensitivities by at least the number of base functions of spectral reflectances of the subject in order to make an accurate estimate of colors of the subject. It is known that spectral reflectances of body skin colors can be displayed in high precision by a linear sum of three base functions. However, in general, in order to display all the spectral reflectances of an object in the natural world, more base functions are considered to be necessary. Therefore, in order to carry out a simple color reproduction in high precision by using a general three-band digital camera having three bands of red (R), green (G), and blue (B), there has been a problem that a subject to be photographed is limited to an object that has spectral reflectances that can be approximated by three base functions.

On the other hand, there has been known a color reproduction system for carrying out a color reproduction by selecting a suitable set of an output profile and an input profile for one input image, as shown in FIG. **23**. In FIG. **23**, an input image from an image input unit **10** is input to a device-independent color converting section **11**A of a color correcting section **11**. The device-independent color converting section **11**A converts colors of the input image into a device-independent color image by referring to an input profile **111**A, and outputs the device-independent color image to a device value converting section **11**B. The device value converting section **11**B converts the device-independent color image into a device value that matches the characteristics of an output unit by referring to an output profile **111**B, and outputs the device value as an output image to an image output unit **12**.

Japanese Patent Publication No. 2678007 discloses a color information correcting unit for correcting a plurality of pieces of read information of a plurality of color components into corresponding recording information for a plurality of record open image colors based on color correction parameters, in the reading of color images.

Further, Japanese Patent Publication No. 2681181 discloses a color data correcting unit that includes an operating unit for correcting colors by carrying out a matrix calculation in color data that has been obtained by digitizing an input signal.

The above-described conventional color reproduction method in the color reproduction system is for carrying out a color reproduction by selecting a suitable set of an output profile and an input/output profile for one input image. According to this method, colors are reproduced based on the same subject characteristic data for all the objects within the image. In other words, colors are reproduced based on object spectrum statistical data. Therefore, the conversion precision is lowered when a plurality of objects are included in the image.

According to the above-described Japanese Patent Publication No. 2678007 and Japanese Patent Publication No. 2681181, although a matrix is selected based on the colors of RGB values, only colors are corrected, and the colors are not converted into colors under the illumination light of the

observation side. Further, as subject characteristic data is not used, colors cannot be reproduced in high precision.

BRIEF SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a color reproduction system capable of reproducing colors in high precision.

More specifically, it is an object of the present invention to provide a color reproduction system capable of reproducing colors of all the objects included in an image in high precision, by dividing the image into images of a plurality of areas and conducting a suitable color conversion in each divided area.

It is another object of the invention to provide a color reproduction system capable of reproducing colors in high precision, by accurately recognizing objects included in a photographed image and conducting color conversion suitable for each object.

It is still another object of the invention to provide a color reproduction system capable of reproducing colors in high precision without having characteristic information of a photographed subject in advance, by photographing color charts of known spectral reflectances and calculating characteristics of the subject from a spectral reflectance of a color chart of a value nearest a signal value obtained when the subject has been photographed.

It is still another object of the invention to provide a color reproduction system capable of reproducing colors in high precision, by estimating colors of various subjects by using a color-photographing unit of a limited number of bands.

In order to achieve the above objects, according to a first aspect of the present invention, there is provided a color reproduction system comprising:

a color image input section; and

a color correcting section for correcting colors of an image of a subject obtained by photographing the subject by the color image input section, wherein

the color correcting section corrects colors by changing over a plurality of color correction parameters according to a subject image signal from the color image input section.

According to a second aspect of the invention, there is provided a color reproduction system relating to the first aspect, wherein

the color correcting section comprises:

an object recognizing section for dividing a subject image input from the color image input section into images of a plurality of areas, and selecting a suitable input profile from among a plurality of input profiles for each divided area;

a device-independent color converting section for converting an image of each area into a device-independent color image by using the input profile selected from among the plurality of input profiles;

an image combining section for combining the device-independent color images converted at divided areas into one device-independent color image; and

a device value image converting section for converting the combined device-independent color image into an output device value image by using a predetermined output profile.

According to a third aspect of the invention, there is provided a color reproduction system relating to the first aspect, wherein the color correcting section has a plurality of input/output profiles prepared by integrating input profiles and output profiles together, and comprises:

an object recognizing section for dividing an input subject image into images of a plurality of areas, and selecting a suitable input/output profile from among the plurality of input/output profiles for each divided area;

a device value image converting section for converting an image of each area into a device value image by using the input/output profile selected from among the plurality of input/output profiles; and

an image combining section for combining the device value images converted at divided areas into one device value image.

According to a fourth aspect of the invention, there is provided a color reproduction system relating to the first aspect, further comprising:

an object recognizing section for dividing a subject image data including information necessary for preparing a plurality of input profiles into images of a plurality of areas, and selecting suitable subject characteristic information from among a plurality of pieces of subject characteristic information for each divided area;

a format converting section for converting a format based on selected subject characteristic information and outputting image data capable of changing illumination by areas;

a device-independent color converting section for calculating an input profile from the illumination-variable image data, selecting a suitable input profile from among the plurality of input profiles based on the calculated input profile, and converting the image in each area into a device-independent color image by using the selected input profile;

an image combining section for combining the device-independent color images converted at divided areas into one device-independent color image; and

a device value image converting section for converting the combined device-independent color image into an output device value image by using a predetermined output profile.

According to a fifth aspect of the invention, there is provided a color reproduction system relating to the first aspect, further comprising:

an area dividing section for dividing an input image into images of a plurality of areas;

a device-independent color converting section for converting the image in each divided area into a device-independent color image by using the plurality of input profiles in parallel;

a conversion result selecting section for selecting a device-independent color image for each area by comparing the plurality of converted device-independent color images;

an image combining section for converting the device-independent color images selected at divided areas into one device-independent color image; and

a device value image converting section for converting the combined device-independent color image into an output device value image by using a predetermined output profile.

According to a sixth aspect of the invention, there is provided a color reproduction system relating to the first aspect, further comprising:

an area dividing section for dividing an input image into images of a plurality of areas;

a first device-independent color converting section for converting the image in each divided area into a device-independent color image by using one input profile;

a second device-independent color converting section for converting the input image in each divided area into a device-independent color image by using an input profile selected from among a plurality of input profiles for each area based on a result of the conversion in the first device-independent color converting section;

an image combining section for converting the device-independent color images converted at divided areas into one device-independent color image; and

a device value image converting section for converting the combined device-independent color image into an output device value image by using a predetermined output profile.

According to a seventh aspect of the invention, there is provided a color reproduction system relating to the first aspect, further comprising:

an area dividing section for dividing an input image into images of a plurality of areas;

a first device-independent color converting section for converting the image in each divided area into a device-independent color image by using one input profile;

a spectral reflectance database for storing information on spectral reflectances of a plurality of objects;

a conversion result judging section for judging a result of the conversion at the first device-independent color converting section by referring to the spectral reflectance database;

a subject characteristic information calculating section for calculating subject characteristic information by selecting information in the spectral reflectance database based on a result of the decision by the conversion result judging section;

a second device-independent color converting section for converting the input image in each divided area into a device-independent color image by using an input profile selected from among a plurality of input profiles prepared based on the subject characteristic information calculated by the subject characteristic information calculating section;

an image combining section for converting the device-independent color images converted at divided areas into one device-independent color image; and

a device value image converting section for converting the combined device-independent color image into an output device value image by using a predetermined output profile.

According to an eighth aspect of the invention, there is provided a color reproduction system relating to the first aspect, further comprising:

an object recognizing section for selecting an input profile to be used from among a plurality of input profiles based on a signal value of an image obtained by photographing using a plurality of color charts of known spectral reflectances;

a device-independent color converting section for converting an image of each area into a device-independent color image by using the input profile selected from among the plurality of input profiles;

an image combining section for combining the device-independent color images converted at divided areas into one device-independent color image; and

a device value image converting section for converting the combined device-independent color image into an output device value image by using a predetermined output profile.

According to a ninth aspect of the invention, there is provided a color reproduction system relating to the first aspect, further comprising:

a spectral reflectance database having spectral reflectances of color charts;

a subject characteristic calculating section for calculating subject characteristic information from a color-chart photographic image based on signal values of an image obtained by photographing using a plurality of color charts of known spectral reflectances and data of the spectral reflectance database;

an object recognizing section for dividing a subject photographic image into images of a plurality of areas, and selecting an input profile to be used from among a plurality of input profiles based on the calculated subject characteristic information;

a device-independent color converting section for converting an image of each area into a device-independent color image by using the input profile selected from among the plurality of input profiles;

an image combining section for combining the device-independent color images converted at divided areas into one device-independent color image; and

a device value image converting section for converting the combined device-independent color image into an output device value image by using a predetermined output profile.

According to a tenth aspect of the invention, there is provided a color reproduction system relating to the second aspect, wherein

the input profile is prepared based on at least one of image input unit information that includes photographic characteristics of an image input unit used for the photographing and information on a set state of the color image input section, observation illumination light information, and subject characteristic information that represents statistical characteristics of spectral reflectances of the photographed subject.

According to an eleventh aspect of the invention, there is provided a color reproduction system relating to the first aspect, wherein

the color correcting section comprises a color estimating section for estimating tristimulus values of the subject under an observation illumination light, based on subject photographic signals obtained by photographing the subject by the color image input section, spectral sensitivity of the color image input section, color matching functions, a spectrum of photographic illumination light, a spectrum of observation illumination light and statistical data of spectral reflectances of the subject, and

the color estimating section uses the statistical data which is changed over according to the subject photographic signals.

According to a twelfth aspect of the invention, there is provided a color reproduction system relating to the first aspect, wherein

the color correcting section comprises a color estimating section for estimating tristimulus values of the subject under an observation illumination light, based on object photographic signals obtained by photographing a plurality of objects of known spectral reflectances by the color image input section, subject photographic signals obtained by photographing the subject by the color image input section, color matching functions, a spectrum of observation illumination light and statistical data of spectral reflectances of the subject, and

the color estimating section uses the statistical data which is changed over according to the subject photographic signals.

According to a 13th aspect of the invention, there is provided a color reproduction system relating to the eleventh aspect, wherein the color estimating section uses the statistical data which is changed over based on a relationship between spectral reflectance data for calculating statistics of spectral reflectances and the subject photographic signals.

According to a 14th aspect of the invention, there is provided a color reproduction system relating to the twelfth aspect, wherein the color estimating section uses the statistical data which is changed over based on a relationship between spectral reflectance data for calculating statistics of spectral reflectances and the subject photographic signals.

According to a 15th aspect of the invention, there is provided a color reproduction system relating to the twelfth aspect, wherein the color estimating section changes over the statistical data based on a relationship between spectral reflectance data for calculating statistics of spectral reflectances of the subject obtained from a relationship between the object photographic signals and spectral reflectances of the objects, and the subject photographic signals.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate presently preferred embodiments of the invention, and together with the general description given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention.

FIG. **1** is a diagram showing a structure of a color reproduction system relating to a first embodiment of the present invention.

FIG. **2** is a diagram showing a detailed structure of the device-independent color converting section **202**.

FIG. **3** is a diagram showing a detailed structure of a device value converting section **204**.

FIG. **4** is a diagram showing a structure of a modification of the first embodiment.

FIG. **5** is a diagram showing a distribution of a spectral reflectance space of subjects in a multi-dimensional space of a spectrum.

FIG. **6** is a diagram showing a structure of a color reproduction system relating to a second embodiment of the present invention.

FIG. **7** is a diagram showing a detailed structure of a device value converting section **222**.

FIG. **8** is a diagram showing a structure of a modification of the second embodiment.

FIG. **9** is a diagram showing a structure of a color reproduction system relating to a third embodiment of the present invention.

FIG. **10** is a diagram showing a format of illumination variable image data by areas **244**.

FIG. **11** is a diagram showing a structure of a color reproduction system relating to a fourth embodiment of the present invention.

FIG. **12** is a diagram showing distributions of certain specific color spaces in a color space of various objects in a natural world.

FIG. **13** is a flowchart showing details of an algorithm for carrying out a processing of the fourth embodiment.

FIG. **14** is a diagram showing a structure of a color reproduction system relating to a fifth embodiment of the present invention.

FIG. **15** is a flowchart showing details of an algorithm for carrying out a processing of the fifth embodiment.

FIG. **16** is a diagram showing a structure of a color reproduction system relating to a sixth embodiment of the present invention.

FIG. **17** is a diagram for explaining a seventh embodiment of the present invention.

FIG. **18** is a diagram showing a structure of a color reproduction system relating to the seventh embodiment of the present invention.

FIG. **19** is a diagram showing a distribution of a spectral reflectance space of a subject in a multi-dimensional space of a spectrum.

FIG. **20** is a diagram for explaining an eighth embodiment of the present invention.

FIG. **21** is a diagram showing a structure of a color reproduction system relating to the eighth embodiment of the present invention.

FIG. **22** is a diagram for explaining a ninth embodiment of the present invention.

FIG. **23** is a diagram showing a structure of a conventional color reproduction system.

FIG. **24** is a block diagram showing a structure of a color reproduction system relating to a tenth embodiment of the present invention.

FIG. **25** is a diagram showing a detailed example of a subject spectral reflectance database in the tenth embodiment.

FIG. **26** is a block diagram showing a structure of an LUT data calculating unit in the tenth embodiment.

FIG. **27** is a diagram showing a detailed example of a database photographic signal in the tenth embodiment.

FIG. **28** is a conceptual diagram for explaining sample photographic signals and a selection of a nearest photographic signal in the tenth embodiment.

FIG. **29** is a block diagram showing a structure of a color conversion LUT calculating unit in FIG. **26**.

FIG. **30** is a block diagram showing a structure of a monitor input signal calculating unit in FIG. **29**.

FIG. **31** is a block diagram showing a structure of a data interpolating unit in FIG. **29**.

FIG. **32** is a block diagram showing a structure of a color reproduction system relating to an eleventh embodiment of the present invention.

FIG. **33** is a block diagram showing a structure of an LUT data calculating unit in the eleventh embodiment.

FIG. **34** is a block diagram showing a structure of a color conversion LUT calculating unit in FIG. **33**.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the present invention will be now be explained in detail with reference to the attached drawings.

First Embodiment

FIG. **1** is a diagram showing a structure of a color reproduction system relating to a first embodiment of the

present invention. This color reproduction system consists of an image input unit **100** for photographing an image of an object, a color correcting section **200** for correcting the input image and generating an output image, and an image output unit **300**.

In the color correcting section **200**, an object recognizing section **201** recognizes an object within an input image. In other words, an area dividing section **201-1** of the object recognizing section **201** divides the input image into images of a plurality of areas. An input profile selecting section **201-2** selects a suitable input profile from among a plurality of input profiles for each divided area by changing over a switch **205**. A device-independent color converting section **202** has a memory unit for storing a plurality of input profiles **1** to n (**2021** to **202***n*). The device-independent color converting section **202** converts an image in each area into a device-independent color image by using an input profile that has been selected from among the plurality of input profiles **1** to n (**2021** to **202***n*) by the input profile selecting section **201-2**. An image combining section **203** combines the device-independent color images converted into images of divided areas into one device-independent color image. A device value converting section **204** converts the combined device-independent color image into an output image by referring to an output profile **2040**.

FIG. **2** is a diagram showing a detailed structure of the device-independent color converting section **202**. The device-independent color converting section **202** consists of the above memory section for storing the plurality of input profiles **1** to n (**2021** to **202***n*), an input profile preparing section **2031** for calculating an input profile based on at least one set of information of characteristics and setting of an image input unit used for a photographing (image input unit information), spectrum data of an illumination light used for photographing an image of an object by the image input unit (photographic illumination light information), spectrum data of an illumination light at a position where the image of the photographed object is to be observed (observation illumination light information), and statistical characteristics of a spectral reflectance of the photographed object (subject characteristic information), and an input profile working section **2030** for working the prepared input profile onto the input image in each divided area to convert the input image into a device-independent color image.

FIG. **3** is diagram showing details of the device value converting section **204**. The device value converting section **204** consists of an output profile preparing section **2043** for calculating an output profile **2042** based on input information on an output unit (image output unit information), and an output profile working section **2041** for working the prepared output profile **2042** onto a device-independent color image to convert the device-independent color image into an output image.

The use of the above image input unit information makes it possible to convert an input image into a device-independent color image by taking into consideration differences in characteristics of various image input units and differences in the setting of photographing. It is possible to achieve a color reproduction in high precision when the image input unit **100** is a multi-spectrum camera or a digital camera for photographing a plurality of spectrum images.

Further, the use of the photographic illumination light information makes it possible to cancel influence of the illumination light at the time of the photographing. In other words, it is possible to calculate an accurate spectral reflectance of an object itself when the object is photographed by using any illumination light such as, for example, a fluorescent light, an incandescent light, solar beams, etc.

Further, the use of the observation illumination light information makes it possible to convert the colors of a photographed object into colors under any illumination light. For example, by a remote-control reproduction of colors of an object under a different illumination, it is possible to display the colors of the object as if the object is positioned at the place of observation.

Further, the use of the subject characteristic information makes it possible to estimate a color reproduction image in high precision even if the input image has little spectrum information. In other words, it is possible to estimate a spectral reflectance of an object in high precision when an image input unit is a digital camera for photographing a color image of RGB three bands instead of a digital camera for photographing a color image of a plurality of spectra. The subject characteristic information may be a correlation matrix or a base function that represents statistical characteristics of a spectral reflectance.

Further, the use of the image output unit information makes it possible to convert in high precision a device-independent color image into an output image that matches the image output unit **300**. This makes it possible to reproduce colors by taking into consideration differences in characteristics and variations between monitors and between printers.

As explained above, according to the present embodiment, an input image is divided into images of a plurality of areas, and an input profile is to be used for each divided area is selected from among a plurality of input profiles. The input image is converted into a device-independent color image by using a selected input profile. Thus, it is possible to make an accurate decision on the photographed object within an image, and to use an input profile that is suitable for the subject characteristics of the object. Therefore, it is possible to achieve a color reproduction in high precision for all parts of the image.

FIG. **4** shows a modification of the first embodiment. This shows an example of an image processing unit having a plurality of input profiles (**1** to N) by using the subject characteristic information. Usually, it is difficult to pick up an image of only a desired object in one picture. A background of the selected object and other objects are also included in the same picture. When colors of these objects are processed for reproduction by using only the input profile that uses characteristic information of one subject, it is possible to reproduce the colors of the desired object in high precision. However, colors of the background and other objects are not reproduced in high precision.

To solve this problem, a color correcting section **200** in FIG. **4** uses a plurality of input profiles **2021** to **202**N that use characteristic information of various subjects including a person, an animal and a plant. An object recognizing section **201** decides what has been photographed in a certain area within the image based on a signal value of an input image, and selects a suitable input profile from among a plurality of input profiles. A device-independent color converting section **202** works an input profile selected from among a plurality of input profiles **2021** to **202**N onto the input image, thereby to prepare a device-independent color image. It is also possible to prepare a plurality of pieces of subject characteristic information in advance based on colors of objects or based on substances that constitute objects.

Assume that a spectral reflectance space of subjects is distributed in a multi-dimensional space of a spectrum as shown in FIG. **5**. In FIG. **5**, h (λ) represents a spectral

sensitivity of a camera. On the spectral sensitivity of h (λ), a subject spectral reflectance that takes a value of a signal value p1 represents all the points on a line perpendicular to h (λ). When subject information of only one subject is used like the conventional method, p2 of a subject A and p3 of a subject B take the same signal value. Therefore, in the estimate of spectral reflectances of these subjects based on this signal value, these subjects take the same spectral reflectance.

When two sets of subject characteristic information are used for the subject A and the subject B like the present embodiment, it becomes possible to estimate two spectral reflectances for the p2 and p3, based on the same signal value p1. As explained above, by using a plurality of sets of subject characteristics, it is possible to estimate spectral reflectances of subjects in high precision.

Second Embodiment

FIG. **6** is a diagram showing a structure of a color reproduction system relating to a second embodiment of the present invention. This color reproduction system consists of an image input unit **100** for photographing an image of an object, a color correcting section **220** for correcting the input image and generating an output image, and an image output unit **300**.

In the color correcting section **220**, an object recognizing section **221** recognizes an object within an input image. In other words, an area dividing section **221-1** of the object recognizing section **221** divides the input image into images of a plurality of areas. An input/output profile selecting section **221-2** selects a suitable input/output profile from among a plurality of input/output profiles for each divided area by changing over a switch **224**. A device value converting section **222** has a memory unit for storing a plurality of input/output profiles **1** to N (**2221** to **222N**). The device value converting section **222** converts an image in each area into a device-independent color image by using an input/output profile that has been selected from among the plurality of input/output profiles **1** to N (**2221** to **222N**) by the input/output profile selecting section **221-2**. An image combining section **223** combines the device-independent color images converted into images of divided areas into one device-independent color image.

FIG. **7** is a diagram showing a detailed structure of the device value converting section **222**. The device value converting section **222** consists of an input profile **2281**, **2282**, **228N** preparing section **2270** for calculating an input profile based on at least one set of information of characteristics and setting of an image input unit used for a photographing (image input unit information), spectrum data of an illumination light used for photographing an image of an object by the image input unit **100** (photographic illumination light information), spectrum data of an illumination light at a position where the image of the photographed object is to be observed (observation illumination light information), and statistical characteristics of a spectral reflectance of the photographed object (subject characteristic information), an output profile preparing section **2260** for calculating an output profile **2250** based on input information on an image output unit (image output unit information), an input/output profile preparing section **2240** for combining the prepared input profile and the output profile to prepare an input/output profile, and an input/output profile working section **2230** for working the prepared input/output profile onto the input image to convert the input image into an output image.

The use of an input/output profile prepared by combining the input profile and the output profile of the first embodiment makes it possible to convert the input image into a color-reproduced output image at a higher speed.

FIG. **8** shows a modification of the second embodiment. Usually, it is difficult to pick up an image of only a desired object in one picture. A background of the selected object and other objects are also included in the same picture. When colors of these objects are processed for reproduction by using only the input profile that uses characteristic information of one subject like the conventional method, it is possible to reproduce the colors of the desired object in high precision. However, colors of the background and other objects are not reproduced in high precision.

To solve this problem, a color correcting section **220** in FIG. **8** uses a plurality of input/output profiles **2221** to **222N** that use characteristic information of various subjects including a person, an animal and a plant. An object recognizing section **221** decides what has been photographed in a certain area within the image based on a signal value of an input image, and selects a suitable input/output profile from among a plurality of input/output profiles. A input/output profile working section **222** works an input/output profile selected from among a plurality of input/output profiles **2221** to **222N** onto the input image, thereby to prepare a device-independent color image.

Third Embodiment

FIG. **9** is a diagram showing a structure of a color reproduction system relating to a third embodiment of the present invention. This color reproduction system consists of an image input unit **100** for photographing an image of an object, a color correction pre-processing section **240** for converting an input image into illumination variable image data (illumination variable image data by areas) **244**, a color correcting section **245** for preparing an input profile from the illumination variable image data, converting the input image into a device-independent color image, and then converting the device-independent color image into an output image that matches the image output unit, and the image output unit **300** for outputting (displaying and printing) an output image.

The third embodiment is characterized in that the input image has information necessary for preparing a plurality of input profiles, and has an illumination-variable data structure that uses an input profile according to each area within the image. In other words, the input image has the image data of a subject and any one set of the image input unit information, photographic illumination light information, observation illumination light information, and characteristic information of a plurality of subjects, that is necessary for preparing each input profile.

In the color correction pre-processing section **240**, an area dividing section **241-1** of an object recognizing section **241** divides an input image into images of divided areas. A subject characteristic selecting section **241-2** selects a specific subject characteristic from among a plurality of subject characteristics included in the input image. A format converting section **242** carries out a format conversion based on a result of a selection by a photographic illumination light spectrum selecting section **243**, and outputs a converted data as the illumination variable image data by areas **244**.

In the color correcting section **245**, an input profile calculating section **251** calculates an input profile from the illumination variable image data by areas. A device-independent color converting section **246** converts the illumina-

tion variable image data by areas **244** into a device-independent color image by using an input profile that has been selected from among a plurality of input profiles **1** to N (**2461** to **246**N) corresponding to the calculated input profile by changing over a switch **250**. An observation illumination light spectrum data selecting section **247** is also provided, as shown. An image combining section **248** combines device-independent color images by areas into one device-independent color image. A device value converting section **249** converts the device-independent color image into an output image that matches the image output unit by using an output profile **2490**.

FIG. **10** is a diagram showing a format of the illumination variable image data by areas **244**. The illumination variable image data by areas **244** consists of a header **244-1** that includes information on a marker, a format version, a size of an image, number of dimensions of the image, number of areas of the image, etc., photographic characteristic information **244-2** that includes information on camera spectral sensitivity, photographing shutter speed, photographing diaphragm, etc., photographic illumination light information **244-3** that includes information on a starting wavelength, an ending wavelength, a wavelength interval, spectrum data, etc., an area table **244-4** that stores information on each area to which each pixel belongs (object spectrum statistical data to be used), subject characteristic information **1** (**244-5**) that includes information on an object base function and eigen value data **1**, subject characteristic information **2** (**244-6**) that includes information on an object base function and eigen value data **2**, subject characteristic information **3** (**244-7**) that includes information on an object base function and eigen value data **3**, and image data **244-8** that includes data on monochromatic image×number of dimensions of the image. Although FIG. **10** shows data having the three sets of subject characteristic information, it is also possible to include more sets of subject characteristic information.

Fourth Embodiment

FIG. **11** is a diagram showing a structure of a color reproduction system relating to a fourth embodiment of the present invention. The color reproduction system consists of an image input unit **100** for photographing an image of an object, a color correcting section **260**, and an image output unit **300** for outputting (displaying and printing) an output image.

The fourth embodiment is characterized in that after an input image has been divided into images of a plurality of areas, the images in these areas are converted into device-independent color images in parallel by using a plurality of input profiles.

In the color correcting section **260**, an area dividing section **261** divides an input image into images of a plurality of areas. A device-independent color converting section **262** converts image data for each area into a device-independent color image by using a plurality of input profiles **1** to **3** (**2621** to **2623**). A conversion result selecting section **263** compares between results **1**, **2** and **3** of device-independent color images obtained by the conversion based on the plurality of input profiles, and selects one device-independent color image. An image combining section **264** combines device-independent color images that have been selected by areas into one device-independent color image.

A device value converting section **265** converts the device-independent color image into an output image that matches the image output unit by using an output profile **2650**.

Colors of a human body skin and a cloth of clothes form a limited small space in a total color space of various objects in the natural world, as shown in FIG. **12**. Therefore, when colors of a specific subject are reproduced based on subject characteristic information that represents total objects in the natural world, there is small error in the reproduced colors. However, on the contrary, when colors of other objects are reproduced based on characteristic information of a certain specific subject, there arises a large error in the reproduced colors.

FIG. **13** is a flowchart showing details of an algorithm for carrying out a processing of the fourth embodiment. A threshold value used in the following explanation is one example, and the threshold value is not limited to this example. A color difference **3**.**2** means a color difference in L*a*b* space. This is a difference between colors (color difference) that cannot be distinctly recognized as a different color by human beings when the object is in a distance. Although the three sets of subject characteristic information are used for processing them in parallel in the present embodiment, it is also possible to use more sets of subject characteristic information.

First, a chromaticity value is calculated based on total subject characteristic information (at step S1). Next, a chromaticity value is calculated based on specific subject characteristic information **1** (at step S2). Next, a chromaticity value is calculated based on specific subject characteristic information **2** (at step S3). A decision is made as to whether a color difference between the chromaticity value obtained at the step S1 and the chromaticity value obtained at the step S2 is within a threshold value (Δ E3.2) or not (at step S4). When a decision is YES, a result of the specific subject characteristic information **1** is used (at step S8), and images are combined together (at step S9).

When a decision made at the step S4 is NO, a decision is made as to whether a color difference between the chromaticity value obtained at the step S1 and the chromaticity value obtained at the step S3 is within the threshold value (Δ E3.2) or not (at step S5). When a decision is YES, a result of the specific subject characteristic information **2** is used (at step S6), and images are combined together (at step S9). When a decision made at the step S5 is NO, a result of the total subject characteristic information is used (at step S7), and images are combined together (at step S9).

Fifth Embodiment

FIG. **14** is a diagram showing a structure of a color reproduction system relating to a fifth embodiment of the present invention. This color reproduction system consists of an image input unit **100** for photographing an image of an object, a color correcting section **280** for correcting the input image and generating an output image, and an image output unit **300** for outputting (displaying and printing) an output image.

The fifth embodiment is characterized in that after an input image has been divided into images of a plurality of areas, the images in these areas are converted into device-independent color images in hierarchy by using a plurality of input profiles.

In the color correcting section **280**, an area dividing section **281** divides an input image into images of a plurality of areas. A device-independent color converting section **1** (**282**) converts image data for each area into a device-independent color image by first using one input profile **1** (**2821**). A conversion result judging section **283** decides one input profile to be used from among the plurality of input

profiles based on a result of the conversion by the device-independent color converting section **1** (**282**). A device-independent color converting section **2** (**284**) converts the input image divided into areas into device-independent color images again by using an input profile selected from input profiles **2** and **3** (**2841** and **2842**) by changing over a switch **287** according to a result of a decision made by the conversion result judging section **283**. An image combining section **285** combines the device-independent color images by areas into one device-independent color image.

A device value converting section **286** converts the device-independent color image into an output image that matches the image output unit by using an output profile **2860**.

FIG. **15** is a flowchart showing details of an algorithm for carrying out a processing of the fifth embodiment. First, a chromaticity value is calculated based on total subject characteristic information of natural objects (at step **S20**). A decision is made as to whether the chromaticity value obtained at the step **S20** is sufficiently close to the chromaticity value of a specific subject **1** (for example, colors of a human body skin) (at step **S21**). When a decision is YES, a chromaticity value is calculated based on the specific subject characteristic information **1** (at step **S25**). Next, a result of the specific subject characteristic information **1** is used (at step **S26**), and images are combined together (at step **S24**).

When a decision made at the step **S21** is NO, a decision is made as to whether the chromaticity value is sufficiently close to the chromaticity value of a specific subject **2** (at step **S22**). When a decision is YES, a chromaticity value is calculated based on the specific subject characteristic information **2** (at step **S27**). Next, a result of the specific subject characteristic information **2** is used (at step **S28**), and images are combined together (at step **S24**).

When a decision made at the step **S22** is NO, a result of the total subject characteristic information is used (at step **S23**), and images are combined together (at step **S24**).

In other words, in the present embodiment, a chromaticity value is calculated based on the total subject characteristic information of natural objects. The conversion result judging section **283** checks whether the chromaticity value obtained is sufficiently close to the chromaticity value of the specific subject **1** (for example, colors of a human body skin) or the chromaticity value is sufficiently close to the chromaticity value of a specific subject **2** (for example, colors of cloth). When the chromaticity is sufficiently close to a certain specific subject, an area image is converted into a device-independent color image again by using an input profile calculated from the specific subject characteristic information according to this specific subject. In other cases, a result of a conversion using an input profile calculated based on the total subject characteristic information of natural objects is used.

In the present embodiment, there has been explained a case of carrying out image color conversion by using one set of total subject information and two sets of specific subject information. However, it is also possible to use more sets of subject information or to carry out a hierarchical conversion by dividing the process into more steps.

Sixth Embodiment

FIG. **16** is a diagram showing a structure of a color reproduction system relating to a sixth embodiment of the present invention. This color reproduction system consists of an image input unit **100** for photographing an image of an object, a color correcting section **310** for correcting the input image and generating an output image, and an image output unit **300** for outputting (displaying and printing) an output image.

The present embodiment is characterized in that the color reproduction system has a spectral reflectance database, and obtains subject characteristic information for each input image by calculation based on spectral reflectance data.

In the color correcting section **310**, an area dividing section **311** divides an input image into images of a plurality of areas. A device-independent color converting section **1** (**312**) as a spectral reflectance estimating section first converts image data for each area into a device-independent color image of an estimated spectral reflectance by referring to one input profile **1** (**3121**) as a base of all natural objects.

A conversion result judging section **313** compares a spectral reflectance database **317** in which spectral reflectances of various objects have been registered with the spectral reflectance stored in the spectral reflectance database **317** based on the result of the device-independent color converting section **1** (**312**), and checks chromaticity data that is closest to estimated data.

A subject characteristic information calculating section **316** selects data in the spectral reflectance database **317** based on the result of the conversion result judging section **313**, calculates subject characteristic data, and inputs the calculated data to a device-independent color converting section **2** (**315**). A device-independent color converting section **2** (**315**) as a spectral reflectance estimating section **2** prepares an input profile **2** (a base of a red-color natural object) **3152**, an input profile **3** (a base of a blue-color natural object) **3153**, and an input profile **4** (a base of a green-color natural object) **3154**, based on calculated subject characteristic data, and stores these files in a memory section. The device-independent color converting section **2** (**315**) converts the input image divided into areas into a device-independent color image **1** again by using a input profile selected from among the plurality of input profiles **2** to **4** (**3152** to **3154**) by changing over a switch **324** according to a decision made by the conversion result judging section **313**. This is a spectral reflectance estimated by the input profile **2**, **3** or **4**.

The four input profiles **1** (**3121**), **2** (**3152**), **3** (**3153**) and **4** (**3154**) are prepared based on the setting of a photographing side illumination light setting section **314** and an image input unit characteristic setting section **318** and subject characteristic information calculated from data within a spectral reflectance DB.

A device-independent color converting section **3** (**319**) as an illumination converting section converts the device-independent color image **1** into a device-independent color image **2** as a chromaticity value obtained by illumination conversion based on an input profile **5** (illumination conversion) **3195**, by referring to the input profile **5**. The input profile **5** is prepared based on input profile calculation data from an observation side illumination light setting section **320**.

An image combining section **322** combines input device-independent color images **2** by areas. A device value converting section **323** converts the combined image into an output image that matches the device by referring to an output profile **3230**. The output profile **3230** is prepared based on output profile calculation data that is set from an image output unit characteristic setting section **321**. The output image obtained by the device value converting section **323** is output to the image output unit **300**.

The subject characteristic information may be either a correlation matrix or a base function that represents statistical characteristics of a spectral reflectance.

Seventh Embodiment

FIG. **17** is a diagram for explaining a seventh embodiment of the present invention. According to the seventh embodiment, a digital camera **406** photographs a color chart **400** of a known spectral reflectance to form a color chart photographic image **401**. The color chart photographic image **401** is input to an input profile selecting section **402**. Based on a signal value of this image, an input profile **403** to be used for an illumination conversion of an object photographic image is selected and is input to an input profile working section **404**. At the same time, an object photographic image **407** of an object **405** photographed by the digital camera **406** is input to the input profile working section **404**. The input profile working section **404** works the input profile **403** onto the object photographic image **407** to convert the object photographic image into a device-independent color image.

FIG. **18** is a diagram showing a structure of a color reproduction system relating to the seventh embodiment of the present invention. This color reproduction system consists of an image input unit **100** for photographing an image of an object and an image of a color chart, a color correcting section **330**, and an image output unit **300** for outputting (displaying and printing) an output image.

In the color correcting section **330**, an image type selecting section **331** selects a type of an image. An object recognizing section **332** divides an object photographic image into images of a plurality of areas, and selects an input profile to be used from among a plurality of input profiles by referring to signal values of the color chart photographic image and the object photographic image. An input profile preparing section **336** in a device-independent color converting section **333** prepares a plurality of input profiles **3351** to **335**N to be selected by the object recognizing section **332**. An input profile working section **334** prepares a device-independent color image by working an input profile that has bee selected from among the plurality of input profiles **1** to N (**3351** to **335**N) by changing over a switch **332-1** onto the object photographic image. An image combining section **337** combines device-independent color images by areas into one device-independent color image. A device value converting section **338** converts the device-independent color image into an output image that matches the device by referring to an output profile **3380**.

Assume that a spectral reflectance space of subjects is distributed in a multi-dimensional space of a spectrum as shown in FIG. **19**. In this case, h (λ) represents a spectral sensitivity of a camera. On the spectral sensitivity of h (λ), a subject spectral reflectance that takes a value of a certain signal value represents all the points on a line perpendicular to h (λ).

When one conversion matrix is used like the conventional method, the spectral reflectance of a subject is projected to one axis of poor linearity, and thereafter the spectral reflectance is projected to the spectral sensitivity h (λ) of the camera. According to the present embodiment, the conversion matrix to be used is changed over depending on the signal value. Therefore, it is possible to project the spectral reflectance to a plurality of axes of satisfactory linearity. As a result, it is possible to obtain color reproduction in high precision.

Eighth Embodiment

FIG. **20** is a diagram for explaining an eighth embodiment of the present invention. According to the eighth embodiment, a digital camera **508** photographs a color chart **500** of a known spectral reflectance to form a color chart photographic image **501**. The color chart photographic image **501** is input to a subject characteristic information calculating section **503**. The subject characteristic information calculating section **503** calculates subject characteristic information based on data in a color chart spectral reflectance database (DB) **502**. An input profile preparing section **504** prepares an input profile **505** for illumination-converting a subject photographic image **509** based on the subject characteristic information calculated. The subject photographic image **509** is obtained by photographing an object **506** by the digital camera **508**. An input profile working section **507** works the input profile **505** onto the subject photographic image **509** to obtain and output a device-independent color image.

FIG. **21** is a diagram showing a structure of a color reproduction system relating to the eighth embodiment of the present invention. This color reproduction system consists of an image input unit **100** for photographing an image of an object, a color correcting section **430**, and an image output unit **300** for outputting (displaying and printing) an output image.

In the color correcting section **430**, an image type selecting section **431** selects a type of an image. An object recognizing section **432** divides an object photographic image into images of a plurality of areas, and selects an input profile to be used from among a plurality of input profiles based on the object photographic image divided into areas. An input profile preparing section **436** in a device-independent color converting section **433** prepares a plurality of input profiles **1** to N (**4351** to **435**N) to be selected by the object recognizing section **432**. In the present embodiment, the color correcting section **430** includes a subject characteristic information calculating section **437** for calculating subject characteristic information based on data in a spectral reflectance database **438** and giving this calculated information to the input profile preparing section **436**.

An input profile working section **434** prepares a device-independent color image by working an input profile that has bee selected from among the prepared input profiles **1** to N (**4351** to **435**N) by changing over a switch **432-1** onto the object photographic image. An image combining section **439** combines device-independent color images by areas into one device-independent color image. A device value converting section **440** converts the combined device-independent color image into an output image that matches the device by referring to an output profile **4400**.

According to the present embodiment, a signal value of the color chart photographic image is checked. When this signal value is closer to the signal value of the object photographic image, the subject characteristic information is calculated based on the spectral reflectance of this color chart. As subject characteristic is calculated for each input image without having the subject characteristic information, it is possible to carry out a color reproduction in high precision. The subject characteristic information may be a correlation matrix or a base function that represents statistical characteristics of a spectral reflectance.

Ninth Embodiment

A ninth embodiment of the present invention will be explained with reference to FIG. **22**. The ninth embodiment

is characterized in that a color reproduction is carried out by using a program that achieves an illumination conversion processing by areas as one function of an image processing software for a digital camera.

Referring to FIG. **22**, an image file of an object obtained by photographing the object by a digital camera **600** is read. This image is displayed on a display screen **601**, and a predetermined area of the image is designated with a mouse to divide the area. Alternately, the area may be divided automatically by using RGB value rates. Thereafter, a user carries out a suitable illumination conversion for each area within the image by selecting information of subject characteristic information, observation illumination information, etc. An area designation and an illumination conversion are carried out repeatedly on the image to achieve illumination conversion by areas. After that, images in all areas are combined into one image, thereby to achieve color correction in high precision.

According to the above-described first to ninth embodiments, an image is divided into images of a plurality of areas, and colors are converted suitably in each area. Therefore, it is possible to obtain a color reproduction system capable of carrying out color reproduction of all objects included in the image in high precision.

Further, as objects within the photographed image are recognized correctly and a suitable color conversion is carried out for each object, it is possible to obtain a color reproduction system capable of carrying out color reproduction in high precision.

Further, a color chart of a known spectral reflectance is photographed, and subject characteristic is calculated based on a spectral reflectance of a color chart closest to the signal value at the time of the photographing of an object. Therefore, it is possible to obtain a color reproduction system capable of carrying out color reproduction in high precision, without having subject characteristic information in advance.

Tenth Embodiment

FIG. **24** shows a structure of a color reproduction system relating to a tenth embodiment of the present invention. This color reproduction system consists of a digital camera **801** as a color photographing section, a color correcting section **802** having a color estimating function, and a CRT monitor **803**.

The digital camera **801** has three bands of red (R), green (G) and blue (B). The digital camera **801** photographs a subject, and outputs photographic image data (a subject photographic image) of three channels for each pixel, to the color correcting section **802**. The photographic image data of each channel has a signal value of one byte (**0** to **255**). The color correcting section **802** converts the input photographic image data into a monitor input signal suitable for display in the CRT monitor **803**, and outputs the converted signal to the CRT monitor **803**. A subject image is displayed as a color image on the CRT monitor **803**.

The color correcting section **802** consists of a color converting unit **811**, an LUT data memory unit **812**, an LUT data calculating unit **813**, and a characteristic data memory unit **814**.

Each unit of the color correcting section **802** will be explained in detail. First, the color converting unit **811** refers to data R', G' and B' in a lookup table (LUT) within the LUT data memory unit **812** by using RGB values as an address of the photographic image data that has been input from the digital camera **801**. The color converting unit **811** then outputs the LUT data R', G' and B' as monitor input signals to the CRT monitor **803**.

The LUT data memory unit **812** stores in advance LUT data calculated by the LUT data calculating unit **813**. The LUT data consists of monitor input signals corresponding to all the signal values of the photographic image data, that is, R', G' and B' of 256^3. R', G' and B' are one-byte data for each channel.

The LUT data calculating unit **813** inputs data including a spectral sensitivity of the digital camera **801** (hereinafter to be referred to as a digital camera spectral sensitivity), photographic illumination light spectrum, an observation illumination light spectrum, color matching functions, a subject spectral reflectance database, and a monitor profile from the characteristic data memory unit **814**. The LUT data calculating unit **813** calculates the LUT data by using these data. Each data of the digital camera spectral sensitivity, the photographic illumination light spectrum, the observation illumination light spectrum, the color matching functions, the subject spectral reflectance database, and the monitor profile stored in the characteristic data memory unit **814** has the following construction.

The data of the digital camera spectral sensitivity consists of sensitivity data of r (λ), g (λ) and b (λ) each representing a spectral sensitivity of the digital camera **801** for colors R, G and B respectively that are set in 1 nm interval in a wavelength area of 380 nm to 780 nm.

Each data of the photographic illumination light spectrum and the observation illumination light spectrum consists of light intensity data Em (λ) and Eo (λ) of the photographic illumination light spectrum and the observation illumination light spectrum respectively set in 1 nm interval in a wavelength area of 380 nm to 780 nm.

The data of the color matching functions are color matching functions x (λ), y (λ) and z (λ) prescribed by the CIE. These data are interpolated to have data in 1 nm interval in a wavelength area of 380 nm to 780 nm.

The subject spectral reflectance database is a set of a large number of spectral reflectance data measured for objects in the real world. FIG. **25** shows an example of the subject spectral reflectance database. Each spectral reflectance data fi (λ) (i=1 to 1000) has spectral reflectance data in 1 nm interval in a wavelength area of 380 nm to 780 nm, and is managed by a registration number i. The spectral reflectance data fi (λ) registered in the subject spectral reflectance database includes data of objects photographed by the digital camera **801** such as, for example, a plant, a rock, a human skin, a color chart, a picture, a dye, a pigment, etc. The number of objects is assumed as 1000 in this embodiment. However, it is also possible to add data according to the need. The number of registration data is optional.

The monitor profile consists of a matrix M and gradation correction data T. The matrix M is a matrix having elements of XrYrZr, XgYgzg and XbYbZb as XYZ tristimulus values of display colors in input signals (**255, 0, 0**), (**0, 255, 0**) and (**0, 0, 255**) of the CRT monitor **3**.

$$M = \begin{pmatrix} X_r X_g X_b \\ Y_r Y_g Y_b \\ Z_r Z_g Z_b \end{pmatrix}$$

The gradation data are table data γr (R), γg (G) and γb (B) that give a relationship of output luminance to each input

signal of R, G and B of the CRT monitor **803**. Each data is normalized to have a maximum value of 1.

FIG. **26** shows a structure of the LUT data calculating unit **813**. The LUT data calculating unit **813** consists of a database photographic signal calculating unit **821**, a database photographic signal memory unit **822**, a sample data calculating unit **823**, and a color conversion LUT calculating unit **824**. The database photographic signal calculating unit **821** reads all data of the digital camera spectral sensitivity, the photographic illumination light spectrum and the subject spectral reflectance database from the characteristic data memory unit **814** shown in FIG. **24**, and calculates values of photographic signals RiGiBi for spectral reflectance data fi (λ) in the subject spectral reflectance database. The values of the photographic signals RiGiBi are estimated by the following equations.

$$R_i = \int_{\lambda=380}^{780} r(\lambda)E_m(\lambda)f_i(\lambda)d\lambda$$

$$G_i = \int_{\lambda=380}^{780} g(\lambda)E_m(\lambda)f_i(\lambda)d\lambda$$

$$B_i = \int_{\lambda=380}^{780} b(\lambda)E_m(\lambda)f_i(\lambda)d\lambda$$

The values of the photographic signals RiGiBi are stored in the database photographic signal memory unit **822** together with the registration numbers i of the corresponding spectral reflectance data fi (λ) as shown in FIG. **27**. The sample data calculating unit **823** selects ten photographic signals RiGiBi in the small to large order of a distance Di from a predetermined sample photographic signal RsGsBs judged by the following expression. The sample data calculating unit **823** then outputs the registration numbers i and the sample photographic signal RsGsBs to the color conversion LUT calculating unit **824**.

$$D_i=\sqrt{(R_s-R_i)^2+(G_s-G_i)^2+(B_s-B_i)^2}$$

FIG. **28** shows a concept of the sample photographic signal RsGsBs and a selection of the ten photographic signals RiGiBi nearest to the sample photographic signal. A mark of +shows the sample photographic signal RsGsBs, and black marks show the ten photographic signals RiGiBi nearest to the sample photographic signal.

FIG. **29** shows a structure of the color conversion LUT calculating unit **824**. The color conversion LUT calculating unit **824** consists of a correlation matrix calculating unit **831**, a tristimulus value calculating unit **832**, a monitor input signal calculating unit **833** and a data interpolating unit **834**. The registration numbers i of the ten photographic signals RiGiBi selected by the sample data calculating unit **823** in FIG. **26** are input to the correlation matrix calculating unit **831**. The correlation matrix calculating unit **831** inputs the subject spectral reflectance data of the registration numbers i as subject spectral reflectance sample data from the characteristic data memory unit **814** shown in FIG. **24**, and calculates a correlation matrix A, as shown by the following expression, as statistical data of the spectral reflectance of the subject.

$$A = \begin{pmatrix} \langle f_i(380)f_i(380)\rangle\langle f_i(380)f_i(381)\rangle \ \ldots \ \langle f_i(380)f_i(780)\rangle \\ \langle f_i(381)f_i(380)\rangle\langle f_i(381)f_i(381)\rangle \ \ldots \ \langle f_i(381)f_i(780)\rangle \\ \\ \langle f_i(780)f_i(380)\rangle\langle f_i(780)f_i(381)\rangle \ \ldots \ \langle f_i(780)f_i(780)\rangle \end{pmatrix}$$

In the above expression, < > represents an average value of the ten spectral reflectance data.

The correlation matrix A calculated by the correlation matrix calculating unit **831** is output to the tristimulus value calculating unit **832**. The tristimulus value calculating unit **832** calculates XYZ tristimulus values of the subject under the observation illumination light by the following expression based on the correlation matrix A input from the correlation matrix calculating unit **831**, the digital camera spectral sensitivity, the photographic illumination light spectrum, the observation illumination light spectrum and the color matching functions input from the characteristic data memory unit **814** shown in FIG. **24**, and the sample photographic signal RsGsBs input from the sample data calculating unit **823**.

$$C=K_1K_2^{-1}Q$$

where

$$C=(XYZ)^t$$

$$Q=(R_sG_sB_s)^t$$

$$K_1 = \begin{pmatrix} \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_o(\lambda)x(\lambda)\langle f_i(\lambda)f_i(\lambda')\rangle E_m(\lambda)r(\lambda')d\lambda d\lambda' & \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_o(\lambda)x(\lambda)\langle f_i(\lambda)f_i(\lambda')\rangle E_m(\lambda)g(\lambda')d\lambda d\lambda' \\ & \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_o(\lambda)x(\lambda)\langle f_i(\lambda)f_i(\lambda')\rangle E_m(\lambda)b(\lambda')d\lambda d\lambda' \\ \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_o(\lambda)y(\lambda)\langle f_i(\lambda)f_i(\lambda')\rangle E_m(\lambda)r(\lambda')d\lambda d\lambda' & \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_o(\lambda)y(\lambda)\langle f_i(\lambda)f_i(\lambda')\rangle E_m(\lambda)g(\lambda')d\lambda d\lambda' \\ & \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_o(\lambda)y(\lambda)\langle f_i(\lambda)f_i(\lambda')\rangle E_m(\lambda)b(\lambda')d\lambda d\lambda' \\ \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_o(\lambda)z(\lambda)\langle f_i(\lambda)f_i(\lambda')\rangle E_m(\lambda)r(\lambda')d\lambda d\lambda' & \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_o(\lambda)z(\lambda)\langle f_i(\lambda)f_i(\lambda')\rangle E_m(\lambda)g(\lambda')d\lambda d\lambda' \\ & \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_o(\lambda)z(\lambda)\langle f_i(\lambda)f_i(\lambda')\rangle E_m(\lambda)b(\lambda')d\lambda d\lambda' \end{pmatrix}$$

-continued

$$K_2 = \begin{pmatrix} \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_m(\lambda)r(\lambda)(f_i(\lambda)f_i(\lambda'))E_m(\lambda)r(\lambda')d\lambda d\lambda' & \int_{\lambda=350}^{780}\int_{\lambda'=350}^{780} E_m(\lambda)r(\lambda)(f_i(\lambda)f_i(\lambda'))E_m(\lambda)g(\lambda')d\lambda d\lambda' \\ & \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_m(\lambda)r(\lambda)(f_i(\lambda)f_i(\lambda'))E_m(\lambda)b(\lambda')d\lambda d\lambda' \\ \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_m(\lambda)g(\lambda)(f_i(\lambda)f_i(\lambda'))E_m(\lambda)r(\lambda')d\lambda d\lambda' & \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_m(\lambda)g(\lambda)(f_i(\lambda)f_i(\lambda'))E_m(\lambda)g(\lambda')d\lambda d\lambda' \\ & \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_m(\lambda)g(\lambda)(f_i(\lambda)f_i(\lambda'))E_m(\lambda)b(\lambda')d\lambda d\lambda' \\ \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_m(\lambda)b(\lambda)(f_i(\lambda)f_i(\lambda'))E_m(\lambda)r(\lambda')d\lambda d\lambda' & \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_m(\lambda)b(\lambda)(f_i(\lambda)f_i(\lambda'))E_m(\lambda)g(\lambda')d\lambda d\lambda' \\ & \int_{\lambda=380}^{780}\int_{\lambda'=380}^{780} E_m(\lambda)b(\lambda)(f_i(\lambda)f_i(\lambda'))E_m(\lambda)b(\lambda')d\lambda d\lambda' \end{pmatrix}$$

The XYZ tristimulus values calculated by the tristimulus value calculating unit **832** are output to the monitor input signal calculating unit **833**. The monitor input signal calculating unit **833** converts the XYZ tristimulus values into a sample monitor input signal by using the monitor profile input from the characteristic data memory unit **814** shown in FIG. **24**, and outputs the converted signal to the data interpolating unit **834**.

FIG. **30** shows a structure of the monitor input signal calculating unit **833**. The monitor input signal calculating unit **833** consists of a matrix converting unit **841** and a gradation correcting unit **842**.

The matrix converting unit **841** converts the XYZ tristimulus values input from the tristimulus value calculating unit **832** shown in FIG. **29** into R"sG"sB"s by the following expression based on the matrix M of the monitor profile input from the characteristic data memory unit **814** shown in FIG. **24**. The matrix converting unit **841** outputs a result of the conversion to the gradation correcting unit **842**.

$$P=M^{-1}C$$

where

$$P=(R_s"G_s"B_s")^t$$

The gradation correcting unit **842** carries out a gradation correction of R"sG"sB"s input from the matrix converting unit **841** by the following expression based on an inverse function γ^{-1} ( ) of gradation correction data γ ( ) input from the characteristic data memory unit **814** shown in FIG. **24**. The gradation correcting unit **842** outputs the gradation-corrected data as a sample monitor input signal R'sG'sB's to the data interpolating unit **834** shown in FIG. **29**.

$$R_s'=\gamma_r^{-1}(R_s")$$

$$G_s'=\gamma_g^{-1}(G_s")$$

$$B_s'=\gamma_b^{-1}(B_s")$$

The gradation correcting unit **842** carries out the above gradation correction processing to the predetermined sample photographic signals RsGsBs, and stores the results as sample monitor input signals R'sG'sB's in the data interpolating unit **834**. The data interpolating unit **834** obtains by interpolation a monitor input signal corresponding to the value of the photographic signal from among the sample photographic signals RsGsBs, and obtains LUT data having monitor input signal values corresponding to all the photographic signal values.

FIG. **31** shows a structure of the data interpolating unit **834**. The data interpolating unit **834** consists of a data memory unit **851** and an interpolation calculating unit **852**. The data memory unit **851** stores sample photographic signals input from the sample data calculating unit **823** shown in FIG. **26** and corresponding sample monitor input signal values input from the monitor input signal calculating unit **833** shown in FIG. **29**. The interpolation calculating unit **852** carries out an interpolation for all the photographic signal values based on the sample photographic signals near the photographic signal and corresponding sample monitor input signals, thereby to obtain monitor input signals corresponding to the photographic signals. The interpolation-calculating unit **852** then outputs a result of the interpolation to the LUT data memory unit **812** shown in FIG. **24**. The method of interpolation to be used is optional. For signal values that cannot be interpolated based on the sample photographic signals and for signals that are not within the range from 0 to 255, it is possible to cope with the situation by replacing signals by mapping to the near region.

According to the color reproduction system having the above-described structure of the present embodiment, the color correcting section **802** estimates tristimulus color values of subjects by using statistical data A (the correlation matrix A in this example) of the spectral reflectance of the subjects. Colors are estimated by changing over the correlation matrix A as the statistical data according to photographic signals of the subjects obtained by photographing the subjects by the digital camera **801**. More specifically, the correlation matrix A is used by changing over the matrix according to the relationship between the spectral reflectance data fi (λ) for calculating the statistical data of the spectral reflectances and the subject photographic signals. With this arrangement, it is possible to estimate colors in higher precision than when the same statistical data is used for all the subject photographic signals.

Eleventh Embodiment

FIG. **32** shows a structure of a color reproduction system relating to an eleventh embodiment of the present invention. This color reproduction system consists of a digital camera **801** as a color photographing section, a color correcting section **802'**, a CRT monitor **803**, and a color chart **804**. The color chart **804** consists of patches having 16 independent spectral reflectances (a plurality of objects having known spectral reflectances), each patch having a constant spectral reflectance.

The digital camera **801** has three bands of red (R), green (G) and blue (B). The digital camera **801** photographs a subject, and outputs photographic image data (a subject photographic image) of three channels for each pixel, to the color correcting section **802'**. The photographic image data of each channel has a signal value of one byte (**0** to **255**). The color correcting section **802'** converts the input photographic image data into a monitor input signal suitable for display in the CRT monitor **803**, and outputs the converted signal to the CRT monitor **803**. A subject image is displayed as a color image on the CRT monitor **803**.

The color correcting section **802'** consists of a color converting unit **811**, an LUT data memory unit **812**, an LUT data calculating unit **815**, and a characteristic data memory unit **816**. The color converting unit **811** and the LUT data memory unit **812** are similar to those explained in the tenth embodiment, and therefore, their explanation will be omitted here.

The LUT data calculating unit **815** calculates LUT data based on color chart photographic signals obtained by photographing the color chart **804** by the digital camera **801**, an observation illumination light spectrum, color matching functions, a subject spectral reflectance database, color chart spectral reflectance data, and a monitor profile that have been input from the characteristic data memory unit **816**. The LUT data calculating unit **815** outputs the calculated LUT data to the LUT data memory unit **812**.

FIG. **33** shows a structure of the LUT data calculating unit **815**. The LUT data calculating unit **815** consists of a database photographic signal calculating unit **861**, a database photographic signal memory unit **862**, a sample data calculating unit **863**, and color conversion LUT calculating unit **864**.

The database photographic signal calculating unit **861** estimates photographic signals of each spectral reflectance of the subject spectral reflectance database, based on the color chart photographic signals input from the digital camera **801** shown in FIG. **32** and the color chart spectral reflectance data input from the characteristic data memory unit **816**. Within the database photographic signal calculating unit **861**, average signal value data (Rci, Gci, Bci) (i=1 to 16) of signals corresponding to 16 patches of the color chart **804** are first obtained from the color chart photographic signals input from the digital camera **801**. A photographic signal (RiGiBi) of a spectral reflectance fi (λ) in the subject spectral reflectance database is obtained from the following expression.

$$\begin{pmatrix} R_i \\ G_i \\ B_i \end{pmatrix} = \begin{pmatrix} R_{c1} R_{c2} \ \ldots \ R_{c16} \\ G_{c1} G_{c2} \ \ldots \ G_{c16} \\ B_{c1} B_{c2} \ \ldots \ B_{c16} \end{pmatrix} \begin{pmatrix} c_{i1} \\ c_{i2} \\ \vdots \\ c_{i16} \end{pmatrix}$$

In the above expression, cij is an expansion coefficient obtained by expanding an i-th spectral reflectance fi (λ) of the subject spectral reflectance database based on a spectral reflectance pj (λ) (j=1 to 16) of each of the 16 patches of the color chart **804** as given by the following expression.

$$f_i(\lambda) = \sum_{j=1}^{16} c_{ij} p_j(\lambda)$$

The photographic signals calculated by the database photographic signal calculating unit **861** are stored in the database photographic signal memory unit **862**. The database photographic signal memory unit **862** and the sample data calculating unit **863** are similar to those explained in the tenth embodiment, and therefore, their explanation will be omitted here.

FIG. **34** shows a structure of the color conversion LUT calculating unit **864**. The color conversion LUT calculating unit **864** consists of a basis function calculating unit **871**, a tristimulus value calculating unit **872**, a monitor input signal calculating unit **873**, and a data interpolating unit **874**. Registration numbers i of ten photographic signal data selected by the sample data calculating unit **863** shown in FIG. **33** are input to the basis function calculating unit **871**.

The basis function calculating unit **871** receives an input of the subject spectral reflectance data of the registration numbers i as subject spectral reflectance sample data, from the characteristic data memory unit **816** shown in FIG. **32**. The basis function calculating unit **871** then obtains basis functions ρk (λ) (k=1 to 3) of the input data as statistical data of the spectral reflectances of the subject. The basis functions ρk (λ) (k=1 to 3) are obtained as eigen vectors of a correlation matrix of the spectral reflectances.

The tristimulus value calculating unit **872** calculates XYZ tristimulus values of the subject under the observation illumination light as follows, based on the data of a sample signal RsGsBs input from the sample data calculating unit **863** shown in FIG. **33**, color chart photographic signals R (j), G (j) and B (j) (j=1 to 16) input from the digital camera **801** shown in FIG. **32**, the basis functions ρk (λ) (k=1 to 3) input from the basis function calculating unit **871**, an observation illumination light spectrum Eo (λ), color matching functions x (λ), y (λ) and z (λ), and color chart spectral reflectances pj (λ) (j=1 to 16) that have been input from the characteristic data memory unit **816** shown in FIG. **32**. The tristimulus value calculating unit **872** then outputs the calculated XYZ tristimulus values of the subject to the monitor input signal calculating unit **873**.

In other words, the tristimulus value calculating unit **872** calculates the spectral reflectances f (λ) of the subject, and obtains the tristimulus values XYZ under the observation illumination light based on this calculation, from the following expression.

$$X = \int_{\lambda=380}^{780} x(\lambda) E_o(\lambda) f(\lambda) d\lambda$$

$$Y = \int_{\lambda=380}^{780} y(\lambda) E_o(\lambda) f(\lambda) d\lambda$$

$$Z = \int_{\lambda=380}^{780} z(\lambda) E_o(\lambda) f(\lambda) d\lambda$$

The spectral reflectances f (λ) of the subject are obtained from the following expression.

$$F = B(QD)^{-1} G$$

where

$$F = (f(380), f(381), \ldots, f(780))^t$$

$$B = \begin{pmatrix} \rho_1(380)\rho_2(380)\rho_3(380) \\ \rho_1(381)\rho_2(381)\rho_3(381) \\ \vdots \\ \rho_1(780)\rho_2(780)\rho_3(780) \end{pmatrix}$$

-continued

$$Q = \begin{pmatrix} R^{(1)}R^{(2)} \ldots R^{(16)} \\ G^{(1)}G^{(2)} \ldots G^{(16)} \\ B^{(1)}B^{(2)} \ldots B^{(16)} \end{pmatrix}$$

$$D = \begin{pmatrix} d_1^{(1)}d_2^{(1)}d_3^{(1)} \\ d_1^{(2)}d_2^{(2)}d_3^{(2)} \\ \vdots \\ d_1^{(16)}d_2^{(16)}d_3^{(16)} \end{pmatrix}$$

$G=(R_s,G_s,B_s)^t$

In the above expression, elements dk (j) (k=1 to 3, j=1 to 16) of D are expansion functions obtained by expanding the basis functions based on the spectral reflectances of the patches of the color chart **804**.

$$\rho_k(\lambda) = \sum_{j=1}^{16} d_k^{(j)} p_j(\lambda) \ (k = 1 \text{ to } 3)$$

The tristimulus values XYZ calculated by the tristimulus value calculating unit **872** are output to the monitor input signal calculating unit **873**. The monitor input signal calculating unit **873** and the data interpolating unit **874** are similar to those explained in the tenth embodiment, and therefore, their explanation will be omitted here.

According to the color reproduction system having the above-described structure of the present embodiment, the color correcting section **802'** estimates tristimulus color values of subjects under the observation illumination light, based on the spectral sensitivity and the color matching functions of the digital camera **801**, the spectrum of the observation illumination light, and the statistical data of the spectral reflectances of the subjects (the basis functions ρk (λ) (k=1 to 3) in the present example). Colors are estimated by changing over the basis functions ρk (λ) (k=1 to 3) as the statistical data according to photographic signals of the subjects. In other words, the basis functions ρk (λ) (k=1 to 3) are calculated based on the spectral reflectances of the subjects that give signal values close to the subject photographic signals. With this arrangement, it becomes possible to carry out color estimation in high precision.

Other Embodiments

The present invention is not limited to the tenth and eleventh embodiments. It is also possible to implement the invention through various modifications as follows.

(1) In the tenth and eleventh embodiments, the digital camera **801** of RGB three channels has been used as the color photographing section. However, the camera is not limited to this. It is also possible to use a digital camera of four or more channels.

(2) In the tenth and eleventh embodiments, the CRT monitor **803** has been used as the color image output section. However, it is also possible to use other display unit such as a projector, or to use a hardcopy output unit like a printer, instead of the CRT monitor.

(3) In the tenth embodiment, the statistical data of the spectral reflectances of the subjects are calculated based on the spectral sensitivity of the camera and the photographic illumination light spectrum at the time of the photographing. However, it is also possible to calculate in advance the correlation matrix data of spectral sensitivity of a predetermined camera and photographic illumination light spectrum, and to use this calculated data.

(4) In the eleventh embodiment, for photographing the subject and the color chart **804**, it is possible to photograph the subject and the color chart separately when the photographing conditions are the same. Alternatively, it is also possible to photograph the subject and the color chart in one picture at the same time, and to separately take out the subject photographic signals and the color chart photographic signals after the photographing.

(5) In the eleventh embodiment, the number of patches included in the color chart **804** is optional. However, it is desirable that all the spectral reflectance data in the subject spectral reflectance database can be expanded in high precision based on the spectral reflectances of the patches included in the color chart **804**.

As explained above, according to the color reproduction system of the tenth and eleventh embodiments, there is used statistical data of the spectral reflectances of subjects as foresight information based on the subject photographic signals obtained by photographing the subjects by the color photographing unit or the subject photographic signals and the object photographic signals obtained by photographing a plurality of objects of known spectral reflectances by using the color photographic unit. In estimating colors of the subjects under a predetermined illumination light, the statistical data is used by changing over the data according to the subject photographic signals. With this arrangement, it is possible to estimate colors of the subjects in high precision based on a simple system structure using a color photographing unit of a limited number of bands. As a result, it is possible to achieve an accurate color reproduction.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. A color reproduction system comprising:

a color image input section; and

a color correcting section for correcting colors of an image of a subject obtained by photographing the subject by the color image input section, wherein

the color correcting section comprises:

an object recognizing section for dividing a subject image input from the color image input section into images of a plurality of areas, and selecting a suitable input profile from among a plurality of input profiles for each divided area;

a device-independent color converting section for converting an image of each area into a device-independent color image by using the input profile selected from among the plurality of input profiles;

an image combining section for combining the device-independent color images converted at divided areas into one device-independent color image; and

a device value image converting section for converting the combined device-independent color image into an output device value image by using a predetermined output profile.

2. A color reproduction system according to claim **1**, wherein the input profile is prepared based on at least one of image input unit information that includes photographic characteristics of an image input unit used for the photographing and information on a set state of the color image input section, observation illumination light information, and subject characteristic information that represents statistical characteristics of spectral reflectances of the photographed subject.

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